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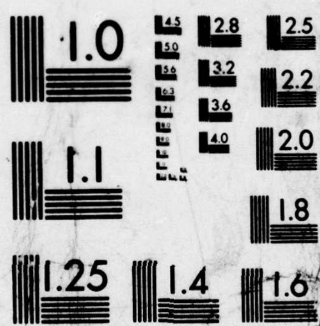

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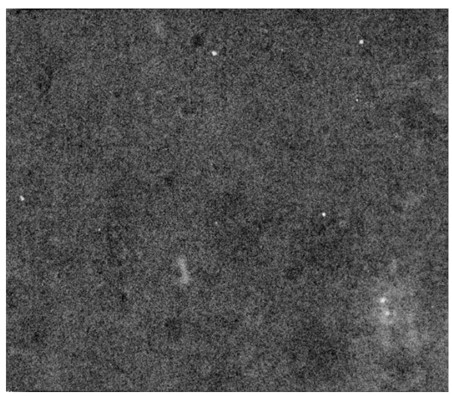
DESIGN AND DEVELOPMENT PROGRAMS

C. David Weimer, *Project Leader*
Paul E. Palatt

October 1976

INSTITUTE FOR DEFENSE ANALYSES
COST ANALYSIS GROUP



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This study report presents findings and conclusions resulting from a one-year study of the impact of reliability guarantees and warranties on the design and development process of selected candidate electronics subsystems. Eleven electronics subsystems, representing the three major Services and involving seventeen industrial contractors, are investigated. (Continued)		

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The objectives of the study are to identify and document the actual impacts observed for the candidate development programs, areas of potential warranty impact, barriers to achieving increased beneficial impacts, problem areas associated with warranty application, and actions that OSD and the Services should consider to improve the application and implementation of equipment warranties.

The analysis consists of combining the results of many Government and contractor management interviews with contractor responses to a standard research questionnaire that was developed to provide a common structure for recording information describing contractor experience with warranties.

The principal findings of the study are in the areas of (a) warranty requirements and application, (b) impact of warranties on candidate development programs, (c) impact of warranties on candidate product designs, and (d) conditions leading to increased warranty impact. It was found that relatively small design and development program impacts were occurring as the result of current warranty application. The potential for substantial impacts was found, however, if uncertainties in the warranty acquisition decision process were eliminated and if specification relief were granted. Other barriers to increased beneficial impacts were found to be the constraints imposed by limited program funding and compressed development schedules.

Based on the study findings, conclusions are drawn regarding the warranty impact on the candidate subsystems examined during the study. It was concluded that the warranty application has been uncertain and imperfect, that warranty options are presently not providing strong design and development incentives for achieving improved operational reliability, and that while warranty actions have captured contractor management attention, more effort could be expended during development to achieve the warranty objectives.

Guidelines for future policy development resulting from the findings are suggested to improve the application of warranties to electronics subsystems. These guidelines relate to the areas of warranty integration into design-to-cost programs, optimal scheduling for warranty decisions, warranty requirements definition, specification flexibility, reliability data and predictive models, development program funding, and development program schedule flexibility.

STUDY S-483

THE IMPACT OF RELIABILITY GUARANTEES AND WARRANTIES ON ELECTRONICS SUBSYSTEM DESIGN AND DEVELOPMENT PROGRAMS

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October 1976

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FOREWORD

During the past few years, an increasing number of electronics subsystems have been developed with contractual obligations for long-term equipment warranties tied to the achievement of improved operational reliability and maintainability. These new contractual techniques for guaranteeing equipment field performance and for internalizing some of the attendant risk to the equipment contractors have been a source of debate between the Government and contractor interest groups.[1] This debate has centered around issues relating to contractor financial risks, reliability prediction, and equipment maintenance roles.

This original research effort, sponsored by the Office of the Assistant Director, Defense Research and Engineering (Planning), investigates the impact of these early warranty options on the electronics equipment design and development process. Because it is in the engineering development program that most of the concerns expressed by the contractors and the Government can be minimized, the results of this research provide an important input to further warranty policy development.

As discussed in the Introduction, this study is limited in scope (eleven electronics subsystems) and depth of treatment; therefore, some of the findings serve only to identify opportunities for more extensive investigation. However, the findings and conclusions of this study are believed to be transferable to future Service and contractor experiences with warranties.[2]

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[1]Notably, the Council of Defense and Space Industry Associations (CODSIA) and the headquarter staffs of the Services and the Office of the Secretary of Defense (OSD).

[2]The eleven candidate subsystems comprise the total (continued on next page)

The scope of the research is also limited by the original task order to an investigation of the impact of reliability improvement warranties (RIWs) on equipment design and development. However, our investigations reveal that most of the programs under study contain additional forms of potential warranty obligations, such as guaranteed mean-time-between failure (MTBF) provisions or guaranteed logistics support cost (LSC) agreements. Because specific effects of RIW provisions are often impossible to isolate, all similar requirements are included under the generic term, warranty, for the purposes of this study. Impacts attributable to specific types of warranty requirements are identified whenever a clear requirement-impact relationship exists.

Perhaps the most significant observation to be made here is that, based on recent research into allied topics,[1] the research findings are unexpected. These findings present an interesting insight into the complex forces that influence the electronics subsystems development and acquisition process.

(contd) population of electronics subsystems with long-term warranty obligations that were available for our investigation in October 1975. Several additional programs, including the Army's ARN-123 receiver and ARN-124 distance measuring set, the Air Force C-141 Carousel navigation system, and the Air Force Omega navigation system, were negotiated with warranty contract provisions subsequent to the establishment of the candidate subsystems for this investigation.

[1]See, for example, C. David Weimer, *The Application of Design-to-Cost Acquisition Policies to Selected Electronics Subsystem Development Programs*, IDA Study S-459 (1975).

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ACKNOWLEDGMENTS

The authors of this study wish to acknowledge the support and cooperation of the many Government and contractor participants in the research effort.

Within the Government, the project officer, Mr. Michael Keller of ODDR&E (Planning), provided the initial guidance, advice, and support necessary to structure the research problem and plan the research effort. Mr. Myron Bruns, chairman of the OSD Tri-Service Reliability and Support Incentives Working Group during the early days of the research, was instrumental in enlisting the Service support necessary to pursue the data gathering. The authors are particularly indebted to the Service project offices that arranged interviews and discussions that provided valuable insights into the complex nature and application of the evolving warranties. The project office support was also important in providing warranty requirements data and the necessary authorization and endorsement for IDA visits to the many contractor organizations responsible for developing the candidate subsystems.

The subsystem equipment contractors played the central role in the research. Through multiple interviews with the management and engineering personnel of the seventeen contractor organizations involved, the research team was able to structure the research and gain many useful insights into the subtleties surrounding warranty impacts. The basis of our research findings depended in large measure upon complete and timely responses to research questionnaires, and contractor cooperation in this area was outstanding; sixteen out of seventeen questionnaires were completed and returned.

The authors also wish to thank Mrs. Jean Shirhall, the technical editor, and the members of the IDA Technical Review Board, Mr. Howard Gates, Mr. Myron Bruns, and Mr. Richard Cheslow, who read the manuscript and provided many helpful and constructive suggestions.

LIST OF ABBREVIATIONS

BITE	Built-in Test Equipment
COD	Correction of Deficiencies
CODSIA	Council of Defense and Space Industry Associations
CTR	Cost to Repair
DSARC	Defense Systems Acquisition Review Council
DTC	Design-to-Cost
ECP	Engineering Change Proposal
EMC	Electro-magnetic Compatibility
ETI	Elapsed Time Indicators
FLU	First Line Units (first level of disassembly below system level that would be carried as a line item of supply at the base level)
FMEA	Failure-Mode-Effects Analysis
GSE	Ground Support Equipment
IC	Integrated Circuit
LRU	Lowest Replaceable Unit
LSC	Logistics Support Cost
MIL-STD	Military Standard
MLSC	Measured Logistics Support Cost
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
R&M	Reliability and Maintainability

RFP	Request for Proposal
RFQ	Request for Quotation
RIW	Reliability Improvement Warranty
RTOK	Retest OK
SRA	Ship Replaceable Assembly
SRU	Shop Replaceable Unit
STE/AGE	Special Test Equipment/Aerospace Ground Equipment
TAT	Turn-around Time
TLSC	Target Logistics Support Cost

EXECUTIVE SUMMARY

A. INTRODUCTION

This study report presents the findings and conclusions of a one-year study of the impact of reliability guarantees and warranties as measured by changes in electronics subsystem design and development program effort.[1] The study analyzes the experiences of seventeen contractors who participated in the development of eleven electronics subsystems that were candidates for reliability guarantees or warranties. These electronics subsystems, shown in Figure S-1, comprised the total population of electronics equipment under multi-year warranty consideration at the initiation of the research.[2]

The research effort was based on the premise that contractors with potential warranty obligations would undertake additional development efforts that would influence the equipment design and change the development program effort in order to improve equipment reliability and minimize their financial risk under the warranty. It was planned that the study would identify and document those initiatives, and that insights drawn from the findings would enable new development programs to be structured more effectively. Acquisition policy changes or initiatives

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[1]Development program effort has been described in terms of a percentage increase or decrease over current expenditures for manhours and materials according to functional elements of a standardized development program task breakdown.

[2]One possible exception is the Navy APN-194 absolute altimeter, which was being produced under a limited, two-year warranty by Honeywell, Inc. Several other subsystem development programs incorporating warranties were planned subsequent to the selection of the candidate subsystems.

No.	Subsystem	Status 6/30/76	Development Contractor(s)
1.	ARN-118/119 TACAN[a]	Prod.	Collins[c] General Dynamics
2.	ARC-164 UHF Radio[a,b]	Prod.	Magnavox[c] Collins RCA
3.	APN-209 ABS. Altimeter[a]	Prod.	Honeywell[c] Hoffman
4.	ASN-128 Doppler[a]	Eng. Dev.	Singer-Kearfott Teledyne/Ryan
5.	SLQ-31/32(V) EW Suite[a]	Eng. Dev.	Hughes Raytheon
6.	B-1 ECM Suite[a]	Eng. Dev.	Cutler Hammer/AIL
7.	F-16 Radar[a]	Eng. Dev.	Westinghouse[c] Hughes
8.	F-16 Inertial Navigation Sys.	Eng. Dev.	Singer-Kearfott
9.	F-16 Fire Cont. Computer	Eng. Dev.	Delco
10.	F-16 Flight Cont. Computer	Eng. Dev.	Lear-Siegler
11.	F-16 Radar/E-O Display[d]	Eng. Dev.	Kaiser Aerospace
11a.	F-16 Radar/E-O Dis. Elect.[d]	Eng. Dev.	Kaiser Aerospace

Notes:

[a]These subsystems were previously studied by IDA as Design-to-Cost subsystems.

[b]The ARC-164 UHF radio did not have an explicit RIW option during development. However, the development contractors knew that the Air Force was going to select the winner of the competition based upon life-cycle cost (LCC) and that the production contractor was required to guarantee (with profit-loss potential) the achievement of field reliability targets.

[c]Successful bidder for production award.

[d]These two subsystems were combined during the study for purpose of analyses.

Figure S-1. CANDIDATE SUBSYSTEMS FOR WARRANTY IMPACT STUDY

that would improve the warranty experiences of both the Services and equipment contractors were also an expected output of the study.

The research methodology consisted of data-gathering through in-depth interviews with Government and contractor management personnel and the preparation, execution, and retrieval of a comprehensive questionnaire. The questionnaire responses were then combined and analyzed as an aggregate contractor sample response. The interviews were directed to acquiring insights into the issues surrounding the questionnaire responses and also to identifying peripheral areas that were important influences on contractor behavior.

The scope of the study is limited by the selection of the eleven electronics subsystems containing contract warranty provisions, the time span of the research effort, and the necessity to protect competition-sensitive and contractor-proprietary data.

B. PRINCIPAL FINDINGS

The research effort yielded a number of significant findings related to the application and impact of warranties on the candidate programs.

1. Warranty Requirements and Their Application

Our investigations into warranty requirements and their application provided findings in areas of contract requirements, the contractor development environment, equipment maturity, and warranty negotiation.

Most of the programs investigated contained multiple warranty obligations or options geared to the achievement of specified operational reliability. The requirement details were similar for most of the programs examined.

Equipment warranties covering operational performance for time periods exceeding two years were found to be new contract requirements for the candidate contractors, most of whom lacked previous military warranty experience. The warranties therefore represented a completely new contractual commitment for the contractors.

Contractors were not usually able to negotiate the detailed terms and conditions of their warranty obligation until negotiation of the production contract. This situation was found to inhibit important design trade-offs during the engineering development program.

Most (eleven of sixteen) of the contractors described their equipment as a "new technological development" rather than a product improvement over a previous model. The risk associated with predicting the ultimate field reliability of the equipment was found to be increased because of the lack of relevant field data on previous equipment.

Difficulties or critical areas during warranty requirements negotiation were reported in eleven major categories. Measurement of field reliability, definition of relevant failures, and warranty price were the critical negotiating areas most frequently identified by the contractors.

2. Impact on Candidate Development Programs

The overall impact of warranty requirements on the candidate development programs, in terms of the increase in development program effort, was reported to be small. An average impact of 5.5 percent increase in effort was recorded based on all sixteen questionnaire responses. The development program functional elements receiving the greatest impact were contract management, program management, design analysis, data and reports, and financial management.

Major barriers to additional program impacts were also identified. The major constraints, as reported by the contractors, were the uncertainty of warranty requirements, the shortage of additional development funds, the constrained development program schedule, preset unit-production cost goals, and inflexible equipment performance and product specifications.

3. Impact on Product Designs

The impact of warranty options on equipment design was reported to be minor, except for contract-imposed requirements for box seals, elapsed-time indicators, and warranty labels. A small impact was reported in the areas of built-in test circuitry or other means of failure isolation, such as test equipment accommodation.

The primary barrier to design impacts appeared to be the requirement to design equipment suitable for both Service organic maintenance and contractor maintenance.

4. Potential Impact on Candidate Development Programs

Three warranty application conditions that could lead to increased warranty impact were identified and investigated during the research. These conditions were: (1) negotiation of warranty terms and conditions at the beginning of engineering development, (2) elimination of the option status of warranty contract requirements, and (3) greater specification flexibility.

The responses to the research questionnaire indicated that the overall development program effort would have been increased from 5.5 percent to 8.2 percent if the negotiation of warranty terms and conditions had been accomplished prior to the *beginning* of engineering development. The greatest

impact was recorded in program management (10.6%), financial management (10.3%), and contract management (9.4%). Similarly, the program effort would have been increased to 10.5 percent if the warranty terms and conditions were *firm* rather than an option at the beginning of engineering development. The greatest impact was recorded in program management (14%), data and reports (12%), and materials and purchased parts (11.8%). If greater *specification relief* were additionally permitted, the entire system would readjust so that the total development effort (compared with the actual case) would increase only nominally to 5.6 percent. However, the areas of increased effort were now reported to be analyses (9.3%), data and reports (8.0%), and financial management (7.8%).

5. Correlation of Contractor Responses

Certain contractors consistently reported greater increases in development program effort than did other contractors over all conditions examined. For those contractors reporting a warranty impact other than zero, the estimated impact on the candidate development program averaged 12.4 percent. The reported impacts for the *beginning, firm,* and *specification relief* conditions were 12.8, 15.1, and 9.9 percent, respectively. Except for the actual warranty application case, this contractor subset reported an average impact that was 60 percent higher than the total aggregate sample.

Attempts to correlate this contractor subset with other subsets were unsuccessful. Attempts to identify relationships between contractor response and program status, Service sponsor, competitive environment, major system application, and other characteristics were also unsuccessful. No identifiable rationale for specific contractor behavior could be found.

6. Additional Issues Relating to Warranty Impacts

The following additional issues relating to warranty impacts were identified during the research effort:

- Contractor Motivation for Increased Reliability
- Government Credibility for Warranty Success
- Competitive Environment
- Prediction of Field Reliability
- Differences Between Prototype and Production Equipment
- Design-to-Cost vs. Design-for-Warranty
- Technological Innovation vs. Design Conservatism
- Return-on-Investment Considerations
- Cost Impact of Equipment Warranties
- Subsystem Contracting Environment
- Legal Enforceability of Warranty Contracts

These issues, either individually or in the aggregate, were reported to influence contractor behavior during engineering development by helping to create a greater impact or by presenting barriers that precluded further impact.

B. CONCLUSIONS

Based on the findings of the limited research effort, the following conclusions can be drawn regarding warranty impacts *on the candidate subsystems* examined during the study.

1. Warranty Application Has Been Uncertain and Imperfect

The application of warranties to the candidate electronics subsystem development programs was made in an environment of uncertainty created by the experimental nature of the warranty acquisition policy, the lack of previous contractor experience with warranties, the advanced technological status of the equipment, and the lack of definitized warranty requirements during development. This environment and contractor uncertainty about the Government's ultimate exercise of the warranty option resulted in an imperfect application of warranty techniques. Because of these conditions, we believe the warranty experiments represented by the candidate subsystems may not be

conclusive indicators of the success or failure of the Government's warranty policy.

2. Warranty Options Are Not Yielding Design and Development Incentives for Improved Reliability

Given the uncertainties surrounding the application of warranties and the observed impacts on the candidate programs, it is concluded that warranty options are not changing the equipment design and development process in ways that would either significantly improve the inherent reliability of the equipment or provide necessary additional information to contractors regarding expectations of future equipment field reliability. Presently, the candidate warranty options can be better characterized as similar to fixed-price options for future maintenance of production equipment.

3. The Potential Exists for Increased Warranty Impact

There is a potential for increased beneficial warranty impact on the equipment design and the development process if uncertainties and barriers surrounding warranty application are removed. Elimination of the optional nature of present warranty programs, for example, appears to be an important step. The increased impact can be achieved most efficiently if maximum allowable specification relief accompanies changes in warranty policy. Realization of the increased impact could necessitate longer development schedules and additional development funds because of the increased effort involved.

4. Warranty Options Have Captured Management Attention

The interviews and questionnaire responses demonstrated that warranty options have attracted the attention and concern of Service and contractor management. This concern has been prompted by the great uncertainties surrounding the candidate

program outcomes. Steps to translate this concern into positive action for improved equipment reliability are potentially available (see below).

D. GUIDELINES FOR WARRANTY POLICY DEVELOPMENT AND APPLICATION

The findings derived from Government and contractor interviews and the data retrieved during this research study support several guidelines for continued warranty policy development.

1. Optimal Scheduling for Warranty Decisions

In order to achieve maximum benefits from equipment warranties, the maintenance philosophy for the candidate equipment should be established by the completion of the equipment's advanced development stage, i.e., before DSARC II. The option process for exercising warranties should be discarded as counterproductive to optimizing equipment design and to achieving increased equipment reliability and maintainability through the development process.

2. Warranty Requirements Definition

The specifications and requirements for future equipment warranties should be negotiated early in the equipment development program, preferably during negotiation of the engineering development contract. These requirements should be treated the same as equipment design or performance specifications.

3. Integration of Warranties with Design-to-Cost Programs

The application of warranties to programs that already contain design-to-cost goals should initiate a reassessment of the production cost targets to minimize the sum of future acquisition and operational costs. A formal process should be established to enable contractors and Service project officers

to revise unit-production cost goals if such a change can be justified on the basis of reduced life-cycle costs.

4. Specification Flexibility

Specification flexibility for non-critical requirements assumes a role of even greater importance when contractors are required to assume additional responsibilities for equipment performance. Thus, specification flexibility should be an integral part of each warranty procurement.

5. Reliability Data and Predictive Models

To aid in improving reliability prediction, retrieval of current and past field reliability data on all generic equipment suitable for warranty application should be continued. Efforts also should be increased to predict more accurately future field reliability from demonstration test data. These initiatives should be taken with help from, and feedback to, the industrial contractor sector.

6. Development Funding and Schedule Flexibility

Preparations for meeting equipment warranty guarantees may require additional development time and funds. The Defense Department should recognize this possibility and take steps to ensure that additional time and money are available.

I

INTRODUCTION

A. BACKGROUND

During the past decade, the Department of Defense has been concerned with ways to increase the availability of operational equipment and to decrease the costs associated with operations and support.[1] This concern has been focused on those systems and subsystems that most often lead to poor availability because of deficiencies in reliability or maintainability. In many instances, electronics subsystems proved to be the critical elements of complex systems that restricted system reliability, maintainability, and ultimately, system availability. Efforts to improve field experience with electronics systems and subsystems have included equipment improvement and retrofit programs, greater emphasis upon fault isolation and built-in test capability, integrated test facilities, improved maintenance training, and contractor guarantees or warranties for equipment field performance.

Contractor equipment warranties covering equipment operation over periods longer than one year were initiated within the Defense Department by the Navy in 1967 with the negotiation of five-year "failure-free" warranties for navigational gyro platforms produced by the Lear Siegler Corporation. Although the Lear Siegler warranty covered equipment that already had accrued

[1]Availability is the primary measure of subsystem utility and effectiveness based upon the assumption that "available" equipment is operating in accordance with all design and performance specification values, including reliability.

field operating experience and had an established operational reliability history, subsequent Navy contracts for aircraft altimeters (Honeywell APN-194) and radio receivers (Northrop Omega) extended the failure-free warranty concept to provide coverage from initial equipment deployment up to a two-year operational period. In 1973, the possibility of extended-year warranty provisions was introduced into several Service electronics development plans in response to a request by the Office of the Secretary of Defense that trial use of warranties be introduced in the acquisition and initial operation of a number of candidate electronics subsystems.[1] This action was motivated, in part, by the commercial successes achieved by the airlines with equipment warranties and by the successful results of the early Navy applications.

Since 1973, the trial application of extended-term equipment warranties has been encouraged by subsequent OSD memorandums that have clarified the concept, formulated application guidelines, and established working groups within OSD and the Services to develop improved policies and procedures for motivating contractor performance under warranty contract provisions.[2] During this period, several studies were made of the conceptual basis for warranty use, the details of warranty provisions, and the experiences of both the Government and its equipment contractors during the negotiation of production contracts containing warranties.[3]

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[1]OSD Memorandum to the Service Secretaries, *Trial Use of Warranties in the Acquisition Process of Electronics Subsystems*, 17 August 1973.

[2]ASD(I&L) Memorandum to the Service Assistant Secretaries, *Trial Use of Reliability Improvement Warranties in the Acquisition Process of Electronic Systems/Equipments - Action Memorandum*, 14 August 1974. ASD(I&L) Memorandum to Assistant Secretaries, same subject as preceding memo, 1 November 1974. OSD Memorandum to the Assistant Secretaries of the Military Departments (R&D), (I&L), *Tri-Service Reliability and Support Incentives Group*, 5 September 1975. ASD(I&L) Memorandum to the Assistant Secretaries of the Services, *Reliability Improvement Warranty Guidelines*, 16 September 1975.

[3]The reader is referred to Appendix F, "Annotated Bibliography," for more information.

In compliance with the OSD directives, the Services subsequently introduced options for warranties or maintenance guarantees into a number of electronics subsystems currently in development. The subsystems selected were initially limited to those that had been designated as experimental design-to-cost acquisitions. As warranty option contract clauses and requirements were developed, however, the application of warranties was increased. The most recent application of warranty options was for the major avionics equipment being developed for the Air Force F-16 air combat fighter aircraft.

Two studies by the Institute for Defense Analyses addressed warranties for electronics subsystem acquisitions as part of a broader study of ways to reduce electronics costs and improve electronics reliability.[1] The 1974 Electronics-X study found that equipment warranties could provide strong contractor motivation to design equipment for increased reliability through the internalization of field reliability and maintenance costs. The subsequent Design-to-Cost (DTC) study found a potential for significant equipment design and development program impacts resulting from the early introduction of warranties into candidate DTC programs. A study recommendation for a detailed examination of the impact of warranty options on equipment design and the engineering development program resulted in the present research effort.

B. RATIONALE AND APPROACH

Based upon the previous IDA study of DTC programs containing reliability improvement warranty (RIW) requirements, there appear to be a number of activities or phases in the equipment

[1]Howard P. Gates, Jr., et al., *Electronics-X: A Study of Military Electronics with Particular Reference to Cost and Reliability*, IDA Report R-195 (1974); and C. David Weimer, *The Application of Design-to-Cost Acquisition Policies to Selected Electronics Subsystem Development Programs*, IDA Study S-459 (1975).

design and development process that could be significantly affected by the imposition or expectation of future contractor maintenance responsibilities. Before investigating these areas, however, it is necessary to examine the premise that actions leading to greater equipment reliability can be identified in the design and development process.

The primary motivations for establishing warranty contracting arrangements are to increase equipment mission availability, through increased field reliability, and to decrease equipment maintenance costs, through both increased field reliability and improved equipment maintainability. Therefore, an assessment of warranties as a procurement tool, must also examine the motivations and opportunities available for achieving these objectives.[1]

1. Methods for Achieving Reliability and Maintainability Goals

A review of the literature and DoD policy directives and memorandums reveals that the objectives of increased equipment reliability and improved maintainability can be achieved during two major phases of an equipment life cycle. First, increased reliability (and maintainability) can be achieved through greater effort during design and development. This has been the demonstrated approach to reliability for both the NASA and military space programs, in both of which equipment cannot be repaired or maintained after deployment.[2] The second opportunity to improve reliability and maintainability occurs in the operational phase, after equipment development has been completed. Based on operational experience, the equipment can be redesigned and new components can be retrofitted in the field to "fix" reliability

[1]These objectives are assumed to be subject to trade-offs within the overall goal of reducing equipment total life-cycle costs.

[2]See for example, Air Force Studies Board, National Research Council, National Academy of Sciences, "Reliability in Aeronautical Avionics Equipment," (Washington, D.C., 1975).

problems uncovered during operational use. This approach is the one that has traditionally been followed, particularly with electronics subsystems. But unfortunately, this method has proven to be extremely costly and has seldom restored reliability to acceptable levels.[1]

Both approaches to improved reliability involve a design effort, whether initially or in a redesign of production configuration equipment. And both approaches require proving the design through a test-fix-test process. These actions constitute the heart of the initial reliability development and demonstration program, as well as any subsequent product improvement program.

2. Contractor Motivations for Improved Reliability During Design and Development

The rationale presented above can now be applied to the conditions imposed upon a contractor who is developing equipment that will (or at the Government's option, may) be covered by a warranty during the first several years of field deployment.

Equipment warranties have been developed in an attempt to internalize the problem of degraded field reliability to the equipment manufacturer such that he will have a strong incentive to minimize reliability problems in operational equipment and respond effectively to any problems that become evident as equipment is placed in use. The incentive mechanism is contractor financial profit or loss, depending upon the difference between the measured performance of the equipment and the predicted performance used to establish the price of the warranty agreements.

[1]The Delco Carousel inertial navigation subsystem is a notable exception to this statement. General Motors invested several millions of its own money but did successfully improve field reliability under airline conditions to meet the warranty MTBF goal of 1000 hours.

The price of the warranty will be negotiated, based upon the expected or specified field reliability.[1] The contractor, accordingly, must take those actions during design and engineering development that will reasonably assure that the specified field reliability will be achieved and that the warranty will be a profitable part of the overall equipment development program.

Emphasizing the design process as the primary method of achieving improved reliability under conditions of warranty obligation has been consistently recognized by DoD organizations. Evidence of this recognition is contained in the DoD statements quoted in Figure 1.

Date	Organization	Key Statements
14 Aug 73	OSD (Director of Defense Research & Engineering)	"Many techniques (to achieve greater field reliability) have been employed ... i.e., more ... reliable products are designed.... "
24 July 74	USAF(Headquarters)	"Contractors will be motivated to ensure that their equipment's reliability and maintainability are given appropriate attention at the time it is initially designed, since this could affect its subsequent repair or replacement costs."
14 Aug 74	OSD (Installations & Logistics)	"The objective of a RIW is to motivate and provide an incentive to contractors to design and produce equipment which will have low failure-rates and low repair costs...."
11 June 76	OSD (Joint Logistics Commanders)	"The use of RIWs on selected hardware can provide additional motivation to the contractors to consider operational supportability factors during the design and development process.

Figure 1. EVIDENCE OF WARRANTY IMPACT ON DESIGN AND DEVELOPMENT

[1]If all goes according to predictions, the warranty becomes a maintenance contract with fee or profit incentives to improve reliability and reduce maintenance costs during its term.

Another closely related problem that must be addressed in the design and development process is the inability to accurately predict ultimate field reliability from development test results.[1] The Defense Department recognized this particular problem in a recent memorandum that emphasized that field reliability, support costs, and potential for reliability growth should be "reasonably predictable" prior to RIW price bid.[2] The Council of Defense and Space Industry Associations (CODSIA) responded to this RIW implementation directive by suggesting that the "risk of reasonable predictability ... can be satisfactorily mitigated only by providing for increased development and environment testing...."[3]

Improved field reliability and maintainability, therefore, are perceived by both the Government and industry as requiring design and development attention either during engineering development or after operational experience in the field. And since the terms and conditions of warranty contract agreements can include severe cost penalties[4] for unsatisfactory reliability after field deployment, the achievement of "satisfactory" reliability must necessarily be accomplished in the development stage. It is then that efforts must be taken to answer the two questions: How can the specified reliability be achieved and demonstrated through design and test? What will the ultimate reliability be in the field with production-type equipment?

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[1]Perhaps the problem of predictability is the primary one to be solved. The question is whether the predicted reliability is an accurate estimate of ultimate field reliability.

[2]ASD(I&L) Memorandum for the Service Secretaries, *Reliability Improvement Warranty Guidelines*, 16 September 1975.

[3]CODSIA Position Paper, "Recommendations on Reliability Improvement Warranty (RIW)," RIW Task Group, Case 19-5, 30 December 1975.

[4]The term "penalty" is used generically throughout this report to describe reduction in contractor profit or an increase in nonreimbursable costs resulting from deficiencies in equipment or contractor performance.

3. Impacts Resulting from Warranties

Changes in the equipment design configuration as a result of warranty obligations can be expected for several reasons, in addition to improving the inherent system reliability. The very nature of the warranty option will dictate design provisions. Secure equipment seals, for example, may be needed to protect against unauthorized entry or repair. Elapsed operating time indicators may also be installed to monitor the reliability operating time interval on a replaceable unit. Other changes in design are possible to improve maintainability, such as including built-in test circuitry and simplifying the design to permit easy repair or replacement of component parts.

In a similar way, changes in the "standard" development program can be anticipated to better predict field maintainability and reliability.[1] More design analysis should be expected, additional environmental testing could be necessary, and detailed analyses involving prediction of reliability and future anticipated maintenance experience might be required.

Thus far, it might be assumed that a warranty impact can be anticipated only if a new equipment design is to be developed. The potential for warranty impact on a design and development program is not limited to new equipment designs, however; it exists whenever any one of several conditions is present. Some of the criteria sufficient for an impact resulting from the ultimate requirement to guarantee equipment maintenance cost and field reliability are listed below:

(1) A new equipment design is to be developed.
(2) "Off-the-shelf" equipment does not presently meet reliability goals or specifications.

[1]There is, of course, no "standard" electronics subsystem development program format. But the ingredients of a development program, i.e., design reviews, failure analyses, and reliability demonstration test programs, are heavily regulated by Government specifications and Service program planning documents.

(3) Necessary modifications to existing equipment will affect reliability or maintainability.

(4) Proposed equipment must be designed for *either* organic *or* contractor warranty maintenance.

(5) Operating environment has changed (increased severity) for the proposed equipment.

(6) Contractor has little or no previous long-term product warranty or support experience.

C. STUDY OBJECTIVES AND SCOPE

The objective of this study was to investigate, record, and analyze the impact of warranty options upon the design and development process of selected candidate electronics subsystems. Detailed objectives of the study were as follows:

(1) Document actual impacts observed for candidate programs.

(2) Identify areas of potential RIW impact.

(3) Identify barriers to achieving beneficial impacts.

(4) Identify dysfunctional elements associated with RIW application.

(5) Identify actions that OSD and the Services should consider to improve the application and implementation of RIWs.[1]

Because the earlier DTC study at IDA had developed information on a number of electronics subsystems, seven of those subsystems were selected for analysis in this study.[2] In addition, four other candidate electronics subsystems being developed with warranty option provisions were selected for study. These subsystems were all avionics being developed for the Air Force

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[1]These objectives are as stated in the IDA Task Order, Appendix A.

[2]Weimer, *The Application of Design to Cost Acquisition Policies to Selected Electronics Subsystem Development Programs.*

F-16 fighter aircraft under subcontract to General Dynamics Corporation.[1] A total of eleven candidate subsystems, involving seventeen contractor organizations during development, were thus selected for study. These subsystems and contractors are listed in Figure 2.[2]

The scope of the study was further defined in terms of research concentration after preliminary discussions with both the OSD project office[3] and the IDA Technical Review Board. Five major areas, discussed below, were selected for investigation and analysis.

<u>Contract Requirements</u>. The first area of investigation was the requirements for product warranties that were known or imposed during the development program. An analysis of warranty impacts could not be undertaken without an understanding of the contractual requirements that were forcing the actions.

<u>Contractor Warranty Background</u>. Another variable that plays an important role in the contractor response is past exposure to and experience with warranties. Impacts were believed to be more difficult to identify if the contractor had already incorporated warranty guidelines or procedures into his development process.

<u>Development Program Impact</u>. This was the major area of research. Warranty impacts identified in this area would be important indicators of actions contractors considered necessary to attain better reliability as well as to reduce risk. The results of this research effort could possibly determine the direction of future program planning and policy application.

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[1]The basic General Dynamics (GD) contract with the Government contains warranty option provisions for specific avionics subsystems. These provisions were passed down to subsystem contrators as part of the GD purchase order in essentially the same form as negotiated by GD.

[2]An additional subsystem, the F-16 heads-up display, was considered for investigation as part of the F-16 avionics warranty program. However, subsequent discussions with the F-16 project office revealed that data acquistion would involve European travel. It was decided that the time and cost involved did not justify retaining this program as part of the subsystem sample.

[3]OSD, ODDR&E (Planning).

No.	Subsystem	Service	6/30/76 Status	Govt. PM	Development Contractor(s)	Contractor Location
1.	ARN-118/119 TACAN[a]	USAF	Prod.	ESD	Collins[c] General Dynamics	Cedar Rapids, Iowa San Diego, Calif.
2.	ARC-164 UHF Radio[a,b]	USAF	Prod.	ASD	Magnavox[c] Collins RCA	Ft. Wayne, Ind. Cedar Rapids, Iowa Camden, N.J.
3.	APN-209 Abs. Altimeter[a]	USA	Prod.	ECOM	Honeywell[c] Hoffman	Minneapolis, Minn. El Monte, Calif.
4.	ASN-128 Doppler[a]	USA	Eng. Dev.	ECOM	Singer-Kearfott Teledyne/Ryan	Little Falls, N.J. San Diego, Calif.
5.	SLQ-31/32(V) EW Suite[a]	USN	Eng. Dev.	NAVELEX	Hughes Raytheon	Fullerton, Calif. Santa Barbara, Calif.
6.	B-1 ECM Suite[a]	USAF	Eng. Dev.	ASD	Cutler Hammer/AIL Boeing Aerospace	Deer Park, L.I. Seattle, Wash.
7.	F-16 Radar[a]	USAF	Eng. Dev.	ASD	Westinghouse[c] Hughes	Baltimore, Md. Culver City, Calif.
8.	F-16 Inertial Navigation System	USAF	Eng. Dev.	ASD	Singer-Kearfott	Little Falls, N.J.
9.	F-16 Fire Cont. Computer	USAF	Eng. Dev.	ASD	Delco	Goleta, Calif.
10.	F-16 Flight Cont. Computer	USAF	Eng. Dev.	ASD	Lear-Siegler	Santa Monica, Calif.
11.	F-16 Radar E/O Display[d]	USAF	Eng. Dev.	ASD	Kaiser Aerospace	Palo Alto, Calif.
11a.	F-16 Radar E/O Dis. Elec.[d]	USAF	Eng. Dev.	ASD	Kaiser Aerospace	Palo Alto, Calif.

Notes:

[a]These subsystems were previously studied by IDA as Design-to-Cost subsystems.

[b]The ARC-164 UHF radio did not have an explicit RIW option during development. However, the development contractors knew that the Air Force was going to select the winner of the competition based upon life-cycle cost (LCC) and that the production contractor was required to guarantee (with profit-loss potential) the achievement of field reliability targets.

[c]Successful bidder for production award.

[d]These two subsystems were combined during the study for purpose of analyses.

Figure 2. CANDIDATE SUBSYSTEMS FOR WARRANTY IMPACT STUDY

Equipment Design Impact. The area of equipment design impact was also considered a significant part of the research effort since specific or generic design changes in preparation for warranty obligations would be concrete evidence that changes were occurring and that equipment design was reflecting concern about the possibility of future reliability guarantees.

Potential Development Impacts and Implementation Barriers. Finally, it was recognized that perhaps a number of potential development impacts could be identified that would help both the Government and its contractors achieve greater field reliability and reduce risks as well. Therefore, potential areas of RIW impact and the barriers preventing those impacts from being exploited were also investigated.

The overall research effort was based upon the premise that contractors with potential equipment warranty obligations would undertake efforts to tailor their equipment design and development program effort to improving reliability and minimizing risk. The findings, therefore, will relate to the input side of the development process rather than to the results ultimately achieved by contractor initiatives.

The application of warranties by the Services has thus far been classified as "experimental," and it will be a number of years before the effect of any additional development efforts can be assessed. Therefore, it would be premature at this time to assess the success or failure of the warranty acquisition concept.

D. STUDY METHODOLOGY

The study was conducted in three successive phases. Phase I consisted of selecting suitable candidate programs, reviewing the published literature in the field, and conducting preliminary interviews with both contractor and Government personnel. Phase II consisted of detailed interviews and data-gathering meetings with contractor personnel who were responsible for the development programs. Phase III consisted of analysis of the data and report preparation.

The Phase I effort occupied approximately 90 days, during which the eleven candidate subsystems (shown in Figure 2) were selected, the annotated bibliography (presented in Appendix F) was prepared, and initial project office and contractor visits were conducted.

The results of the Phase I effort proved critical to the conduct and ultimate success of the project. It was found that special access was required to proceed with data-gathering for the F-16 avionics equipment. Thus, a major part of the Phase I effort was spent obtaining the required OSD and Air Force endorsement of the study, which permitted official access to the F-16 program office at the Aeronautical Systems Division (ASD), the prime contractor, General Dynamics Corporation (Ft. Worth Division), and the major avionics subcontractors.[1]

A critical output of the Phase I effort was the decision to structure part of the contractor data-gathering according to a standard research questionnaire. The initial exploratory interview sessions revealed that potential warranty impacts can be affected significantly by the timing, certainty, and program flexibility associated with warranty application. In order to permit comparison among responses under several different contracting conditions, a detailed questionnaire, included as Appendix D, was constructed. This questionnaire was also used as a vehicle for recording information concerning contractor experience with warranties and for acquiring specific case study examples of design and development program impact. The major sections of the questionnaire (Parts B and C) addressed RIW impacts as actually experienced, the potential impacts if the RIW option had been negotiated prior to engineering development, and potential impacts that might be anticipated if RIW had been a firm requirement (rather than an option) from the beginning

[1]Copies of the Air Force and OSD endorsement memorandums are enclosed as Appendixes B and C, respectively.

of the engineering development phase. An additional variant was added to Part C to determine the effect of maximum specification flexibility, a topic that had been raised during the initial contractor meetings as a continuing barrier to potential impacts.

Phase II consisted of in-depth contractor interviews. These interviews comprised a formal briefing by the investigators, which described the task and the questionnaire, and informal discussions of warranty impact, barriers, and contractor experiences. At these meetings, the questionnaire was presented to the contractor program manager for later retrieval. Any additional questions concerning the format or data requirements were also addressed. A number of secondary visits were also made to selected contractors during Phase II to address additional issues, retrieve questionnaires that had not yet been returned, or clarify answers to specific questions. (Appendix E contains the Government and contractor interview schedule.) A total of sixteen of the seventeen questionnaires distributed during the investigation were completed and returned for analysis.

Phase III, data analysis and report preparation, began 16 June and was concluded with delivery of the draft final report on 1 October 1976. The analysis consisted of combining the results of the many interviews with the formal questionnaire responses in an effort to deduce the collective warranty impact. In order to preserve the proprietary and sensitive nature of many of the contractor interviews and questionnaires, all specific references to contractors have been eliminated throughout the report. When contractor data taken from questionnaires are displayed, coded alphanumeric identifiers are used.

E. REPORT ORGANIZATION

This report has been organized to follow the logic and format established for the study tasks as reflected by the contractor questionnaire.

Chapter II identifies the principal features of the warranty contracts and addresses those elements of the requirements that directly bear upon either the design of the equipment or the conduct of the development program. The chapter also summarizes the specific contract features and warranty requirements for the candidate programs.

Chapter III presents background information relating RIW contract requirements to specific programs and contractors. This chapter also describes the environment and conditions under which the warranty contract obligations were established.

Chapters IV, V, VI present the data, analyses, and findings resulting from the many interviews and the questionnaire responses. Chapter IV examines the actual reported impact of the warranty requirements on the candidate development programs. Program impacts are described and coupled with the driving requirements wherever possible; barriers to the achievement of greater impacts are also identified. Chapter V extends the findings of the previous chapter to potential development program impacts under selected conditions relating to warranty application decisionmaking and contractor specification flexibility. Chapter VI addresses the identifiable design changes in the candidate equipment resulting from warranty considerations. These design changes are described in both specific and generic terms as the data retrieved from the contractors permit.

Chapter VII addresses a number of important additional considerations relevant to warranty applications and consequent impacts that were identified during the program office and contractor interviews. Some of these issues are believed to be capable of masking potential impacts that were identified in the preceding chapters.

Chapter VIII summarizes the findings of the research effort and presents the conclusions derived from those findings.

Guidelines for continued warranty policy development are presented for OSD and Service consideration in Chapter IX. Finally, Chapter X identifies a number of areas in which continued study would lead to a greater understanding of the warranty contract environment and how it relates to the development planning process.

II

EQUIPMENT WARRANTY REQUIREMENTS

Section A of this chapter describes the general features of reliability improvement warranties and companion guarantees.[1] Section B summarizes the specific warranty terms and conditions for each of the candidate subsystems as a general frame of reference for the subsequent analysis.

It should be noted that specific requirements for warranties vary according to their application. And like the candidate applications, many of the warranty provisions are truly experimental in nature. Lessons learned during the initial trial procurements could alter future warranty requirements and could also lead to negotiated changes in existing contract arrangements.

Investigations of the candidate subsystems in this study revealed that frequently the basic warranty requirement was accompanied by other guarantees either as an integral part of the contract or as options to be exercised by the Government. Basically, these guarantees fell into two major categories, guarantees for operational mean time between equipment failure (MTBF), and guarantees for Service logistics support costs.[2] Because most of the candidate subsystems were subject to the possibility of more than one type of warranty/guarantee during their development program, each type will described.

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[1]More detailed discussions can be found in several excellent and comprehensive reports prepared by ARINC Research Corporation. A recent summary report is especially recommended: *Guidelines for Application of Warranties to Air Force Electronic Systems*, ARINC Pub. No. 1500-01-1-1451 (Annapolis, Md., 1975).

[2]The F-16 avionics contracts contain firm requirements or options for each of these types of guarantees.

A. GENERAL CONTRACT REQUIREMENTS

1. Reliability Improvement Warranty

A reliability improvement warranty is basically a contractual agreement whereby, for a fixed price, the contractor agrees to repair all failed units (except for explicit exclusions--see below) returned to him during a specified period of time. The terminology relating to reliability improvement stems from the incentives for improving equipment reliability available to the contractor both during development and after field deployment. Some of the key requirements and features of the RIW are described in the following paragraphs.

a. Warranty Period

The warranty period is the time span during which the warranty is in effect. This period can be measured in total calendar time, beginning at equipment delivery; a fixed calendar time period, independent of delivery schedules and production rates; or equipment operating time, measured either by individual equipment operating-time indicators or on an aggregate population-usage basis. Most warranty periods cover a time period of three or more years, during which some of the older equipment is expected to require normal maintenance service and repair.

b. Excluded Failures

Most warranty requirements contain provisions for excluded failures. Equipment failures that can be traced to misuse or mistreatment, for example, are usually excluded from warranty coverage. A number of reasons for possible exclusions are listed below.

- Fire
- Explosion
- Submersion

- Flood and other acts of God
- Aircraft (vehicle) crash
- Enemy action
- Seal broken on unit while outside contractor's control
- External physical damage caused by accidental or wilfull mistreatment
- Internal physical damage caused by accompanying external physical damage due to mistreatment or to tampering by noncontractor personnel
- Induced failures, i.e., failures of hardware items induced by malfunction or improper operation of outside (system interfacing) units
- Consequential-incidental damages
- Improper installation, operation, or maintenance.

c. Unverified Failures

Reliability warranties have provisions to accommodate those units returned under warranty that subsequently are found to operate properly (RTOKs). The parameters of this requirement relate to the percentage of returns that test good, the incurred costs that are included in the warranty price, and the costs to be paid per unverified failure above the percentages covered by the warranty agreement.[1]

d. Usage Rate Adjustment

Most warranties are negotiated and priced on the basis of an expected usage rate over the warranty period. Significant deviations from the intended usage rate require negotiated warranty price adjustments to account for the change in expected failure rates and maintenance costs.

e. Engineering Change Proposals

One of the primary incentives of a warranty is contractor freedom to make continuous reliability improvements in the design of the equipment. The provision that the Government will

[1]Typically, contractors are asked to price RTOK return rates up to 25 or 30 percent of total returns. The Government usually negotiates a nominal test and reissue price ($100/unit) for additional units that test good at the contractor's plant.

accept no-cost engineering change proposals (ECPs) that do not alter equipment form, fit, or function permits contractor design-improvement latitude with the only restriction that all equipment be modified to the latest configuration by the end of the warranty period.

f. Turn-around Time

An important RIW requirement, turn-around time (TAT), specifies the maximum time allowable to repair (and place in storage) failed units at the contractor's plant (or to ship a replacement spare). Since field availability is affected by delays in repair times, penalties are normally assigned through liquidated damage payments or consignment spares in order to keep equipment turn-around time within set time intervals.

2. Mean Time Between Failure Guarantees

One type of guarantee that has accompanied RIWs and, when included, must be considered a part of any contractor response stimuli, is the guaranteed MTBF. Under this type of warranty, the contractor stipulates that the delivered equipment will attain or exceed predetermined values for field reliability. The usual penalty for failure to achieve the predicted reliability has been contractor provision of consignment spares to replace failed units, thereby maintaining field availability. For most of the candidate programs, MTBF guarantees have been incorporated as an additional option, subsidiary to the basic RIW option.[1]

The basic requirements for the MTBF guarantee consist of specified minimum performance levels as a function of equipment reliability maturation, the method of determining or measuring achieved MTBFs, and the term of the guarantee, usually set at time periods marked by the achievement of specified MTBF levels.

[1]All the F-16 programs have guaranteed MTBF options as an additional option to be exercised beyond the RIW.

The principal contractor risk element of an MTBF guarantee is the cost "penalty" associated with providing consignment spares if specified MTBF levels are not achieved and maintained.

3. Logistics Support Cost Guarantee

The third type of equipment guarantee or warranty is the logistics support cost commitment, wherein the estimated Government logistics support cost is computed by means of a standard negotiated cost model using measured field cost, reliability, and maintainability values. The difference between the contractual target logistics support cost (TLSC) and the measured logistics support cost (MLSC) determines the basis for contractor incentive fees or "penalties," which normally include provisions for the "correction of deficiencies."[1]

The warranty or guarantee aspect of the logistics support cost commitment lies in contract "penalties" for failure to achieve a threshold MLSC. In some applications, the Government can demand additional equipment in lieu of penalty payments, which is similar to the requirement for contingency spares under guaranteed MTBF programs. Additional aspects of the LSC guarantee that are similar to RIWs and guaranteed MTBF are provisions for correction of deficiencies if the equipment does not meet certain performance thresholds, such as MTBF.

The LSC concept is another means for the Government to obtain contractual guarantees that the delivered equipment will meet specified levels of reliability and maintainability.[2] The

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[1]The correction of deficiencies (COD) clause takes on greater significance here since it becomes the forcing clause to achieve specified reliability goals, thereby achieving a minimum MLSC.

[2]The LSC formulas usually are dominated by the three major variables: acquisition cost; field reliability, e.g., MTBF; and field maintainability, e.g., mean time to repair (MTTR). The relative importance of these variables depends upon the equipment unit cost, the number of units produced, the level of field reliability, and the complexity of repair actions.

obligation of the contractors is limited over time, provided that the sampling plan for measuring LSC yields favorable results; however, if the COD provisions are activated and the desired LSC is not achieved by contractor actions, the time period of contractor guarantee obligation in many cases could be extended throughout the equipment lifetime.

B. CANDIDATE PROGRAM RIW REQUIREMENTS

This section summarizes the warranty requirements that were either imposed upon the contractors of the candidate subsystems as firm requirements or as options available for exercise by the Government. These requirements are presented in Table 1 in three major groupings: RIW, guaranteed MTBF, and logistics support cost gaurantees.

It should be noted that eight of the eleven candidate programs are still in the engineering development stage and changes in the requirements are still possible prior to contractual commitment.[1] It should also be noted that the Navy design-to-price EW suite program did not include specifically defined RIW requirements, but both contractors (Hughes and Raytheon), were notified by the program office that RIW requirements were under consideration for selected portions of the system and that they should analyze their designs for accommodation to RIW conditions. The latest version of the production Request for Proposal (RFP) available to the investigators requested that the contractors propose RIW as an alternate maintenance concept if they could demonstrate life-cycle cost savings. Thus, despite the fact that specific RIW requirements had not been defined for the competing systems, both contractors were designing and developing equipment with the knowledge that RIW requirements were a potential production contract ingredient.

[1]The requirements shown in Table 1 were current as of 1 June 1976. They are believed to be accurate indicators of the final requirements that contractors were anticipating for production award commitment.

Table 1. SUMMARY OF CANDIDATE EQUIPMENT WARRANTY AND FIELD PERFORMANCE GUARANTEE REQUIREMENTS, 1 June 1976

Warranty Plan	Requirement or Contract Provision	Candidate Subsystem: USAF ARN-118 Tacan	USAF ARC-164 Radio	USAF B-1 ECM Suite	USAF F-16 Radar	USAF F-16 INS	USAF F-16 F/C Computer	USAF F-16 FLT/C Computer	USAF F-16 Radar E/O[1]	USA APN-209 Altimeter	USA ASN-128 Doppler Nav	USN SLG-31/32 EW Suite
	1. Warranty Coverage Basis	Calendar Yr With Common End Date	--	Calendar Yr With Common End Date	Calendar Yr Or Operating Time	Calendar Yr With Common End Date	Calendar Yr With Common End Date	Calendar Yr With Common End Date	Calendar Yr With Common End Date	Calendar Yr With Common End Date	Calendar Yr From Dec 31 of Accept Yr	See Notes 2 and 3
	2. Warranty Period	6 Yr	--	24 Mo	48 Mo[4]	48 Mo	48 Mo	48 Mo	48 Mo	48 Mo	48 Mo	--
	3. Number of Unverified Failures Included in the Warranty Price	30%	--	N/A	All	All	All	All	All	All	2 Per Mo or 25%	--
	4. Turn-around Price for Additional Unverified Failures	$100	--	N/A	--	--	--	--	--	--	$200	--
Reliability	5. Operating Time Or Utilization Adjustment	68 Hr/Mo ± 3.4 Hr	--	Daily Basis	Total Flying Hrs	Total Flying Hrs	Total Flying Hrs	Total Flying Hrs	100 Hr/Mo	30 Hr/Mo ± 3 Hr	20 Hr/Mo ± 2 Hr	--
Improvement	6. No-cost Class II ECP Provisions	Yes	--	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	--
Warranty	7. Approval Time for No-cost ECPs	35 Days	--	N/A	65 Days	65 Days	65 Days	65 Days	65 Days	30 Days	35 Days	--
	8. Maximum Turn-around Time	15 Days	--	N/A	22 Days	22 Days	22 Days	22 Days	22 Days	30 Days	15-30 Days	--
	9. Turn-around Time Penalties	$25/Day	--	N/A	Spares[5]	Spares[5]	Spares[5]	Spares[5]	Spares[5]	N/A	$25/Day	--
	10. Warranty Contract Status (Option or Firm Requirement) During Development	Option	--	See Note 2	Option	Option	Option	Option	Option	Option	Option	--
	1. Initial MTBF Value Guaranteed (Hr)	500	--	--	70[6]	185	415	162	155	--	500	--
	2. Final MTBF Value Guaranteed (Hr)	800	--	--	90[6]	300	640	260	244	--	500	--
Guaranteed MTBF Program	3. Sample Size for Calculating MTBF	All Units in Active Inventory	--	--	All Units in Active Inventory	All Units in Active Inventory	All Units in Active Inventory	All Units in Active Inventory	All Units In Active Inventory	--	N/A	--
	4. Consignment Spares Obligation	Yes	--	--	Yes	Yes	Yes	Yes	Yes	--	Yes	--
	5. Guarantee Contract Status (Option or Firm Requirement) During Development	Option[7]	--	--	Option	Option	Option	Option	Option	--	Option[7]	--
	6. Minimum Time Period for Guarantee (After Award)	39 Mo	--	--	36 Mo	36 Mo	36 Mo	36 Mo	36 Mo	--	48 Mo	--
	1. Number of Units to be Sampled	40	120	--	24	24	24	24	24	--	--	--
	2. Duration of Formal Sampling Program	40 x MTBF	28 Mo	--	3500 FH	3500 FH	3500 FH	3500 FH	3500 FH	--	--	--
Logistics Support Cost Commitment	3. Penalty/Award Fee Threshold	Shared Incentive to 30%	Shared Incentives	--	TLSC[8] +25%	TLSC[8] +25%	TLSC[8] +25%	TLSC[8] +25%	TLSC[8] +25%	--	--	--
	4. Commitment Contract Status (Option or Firm) During Development	Option	Firm	--	Firm	Firm	Firm	Firm	Firm	--	--	--
	5. No-cost ECPs	Yes	Yes	--	Yes	Yes	Yes	Yes	Yes	--	--	--
	6. Approval Time for No-cost ECPs	35 Days	30 Days	--	30 Days	30 Days	30 Days	30 Days	30 Days	--	--	--
	7. Operational Use Hr/Mo/Item	N/A	50 Hr	--	N/A	N/A	N/A	N/A	N/A	--	--	--
	8. Correction of Deficiencies (COD) Clause	No	Yes	--	Yes	Yes	Yes	Yes	Yes	--	--	--

[1] This column combines the requirements of the F-16 radar/electro-optical display and its electronics since both subsystems are being developed under identical contract requirements by the Kaiser Aerospace and Electronics Corporation.

[2] The statement of work says, "It is *planned* that the failure free warranty set forth ... will be implemented at the time of the issuance of the initial production contract...."

[3] Although there was considerable discussion about requesting the competing contractors to submit a bid for RIW, the production RFP (N00039-76-0127(S)) available to the investigators on 1 June 1976 did not present RIW requirements for contractor response.

[4] Two-year extension option.

[5] Prime contractor penalized spare FLUs for delays beyond the 22-day turn-around objective.

[6] Based upon the combined reliability of individual LRUs.

[7] Automatically exercised if RIW option is selected.

[8] The COD clause is activated if MLSC exceeds TLSC by 25 percent.

Proprietary data available to IDA indicate that considerable analytical effort was expended by the contractors to determine potential RIW applicability, subcontract influence, financial risk, logistics considerations, and ultimate support-cost relationships vis-a-vis organic maintenance. Therefore, while the RIW requirements cannot be explicitly delineated for this system, the work of the contractors convinced the investigators that this system should be retained as one of the candidates for analysis.

1. RIW Requirements

As illustrated in Table 1, nine of the eleven candidate programs contain explicitly defined requirements for RIW obligations during the engineering development program. For those nine programs, the RIW is an option to be exercised, based upon the contractor bid at the time of production contract award.

Most of the RIW requirements are similar for the nine candidate programs involved.[1] All but the B-1 ECM suite have warranty periods of four years or longer, have provisions for no-cost ECPs, and have specified equipment turn-around times with penalties for late delivery.

The principal differences in the RIW requirements are in approval time for no-cost ECPs and the coverage of unverified failures. The subcontractors for the F-16 subsystems must wait 65 days for approval before they can unilaterally incorporate no-cost ECPs, whereas the Air Force Tacan and the Army altimeter and doppler navigation system contractors must wait 30-35 days. This difference is the result primarily of the subcontractor relationship between the F-16 equipment contractors

[1]This is not surprising, since ARINC Research Corporation, working as a Service consultant, was the architect of most contractual clauses.

and the prime contractor, General Dynamics. The latter's contract calls for ECP incorporation 30 days after receipt by the Government unless written notification of non-approval is given.

Unverified failures are completely covered by the RIW requirements for all but two candidates--the Air Force Tacan and the Army doppler. For these two systems, a coverage limit has been established (30 and 25 percent, respectively) and additional unverified failures are sources of nominal reimbursement to the contractors.[1]

In general, the RIW requirements of the candidate programs were characterized by their similarities. They represented long-term obligations on the part of contractors to repair and maintain equipment returned from the field and to guarantee equipment availability through specified turn-around times and "penalties" for delay. In every case, these requirements remained as priced options that the Government had the freedom to exercise at the time of production contract award.

2. <u>Guaranteed MTBF Requirements</u>

Seven of the candidate subsystems, including all five of the subcontracted F-16 subsystems, are being developed with contractual options for guaranteed MTBF provisions. Each of the seven subsystems is potentially under the same general requirements, which include total unit sampling, consignment spares supply, and minimum demonstration time periods. Specific MTBF values, as guaranteed, are shown in Table 2.

The guaranteed MTBF provisions for the F-16 equipment are slightly different from the provisions for the Tacan and doppler

[1]Unverified failures are a serious concern of contractors because past experience in avionics has shown that 20-40 percent of all returned units test good at the contractor's plant. The nominal fee paid for each unit returned over the threshold does not usually cover test and turn-around costs.

Table 2. MTBF GUARANTEES FOR CANDIDATE SUBSYSTEMS

Candidate Equipment	Unit MTBF Guarantee (Hours)		
	1st Year	2nd Year	3rd Year
F-16 Flight Control Computer	162	242	260
F-16 Radar E/O Display	155	228	244
F-16 Fire Control Computer	415	600	640
F-16 Fire Control Radar*	70	82	90
F-16 Navigation System	185	284	300
USAF ARN-118 Tacan	500	625	800
USA ASN-128 Doppler	500	500	500

*Radar guarantees are based on individual LRU MTBF values.

navigation subsystems in that the guarantee is an option to be exercised only after the decision is made to select the RIW; the Government may select the RIW with or without the guaranteed MTBF, but the guaranteed MTBF option cannot be exercised independently of the RIW. In the Tacan and doppler navigation contract clauses, the guaranteed MTBF is an integral part of the total warranty requirements and is exercised automatically if the RIW option is selected.

3. Logistics Support Cost Commitment

A logistics support cost commitment is a potential contractual requirement for all the F-16 subsystem candidates and was an ingredient of the ARC-164 radio and ARN-118 Tacan development contracts.[1] These requirements are similar in nature to the preset target logistics support cost values derived through the Air Force logistics command (AFLC) cost formula.[2] Field

[1]The LSC commitment for the F-16 equipment is a firm, basic contract requirement unless the RIW option is selected.

[2]See G. Harrison, *The Development and Analysis of RIW and COD Provisions for the Air Combat Fighter (ACF) Aircraft*, Pub. No. (continued on next page)

measurements demonstrating the achievement of the LSC will determine contractor profit or loss.[1]

4. Candidate Requirements Summary

An overview of the warranty requirements for the candidate programs shows that all of the programs are being developed with either explicitly defined or implicitly understood requirements for contractor guarantees for equipment field reliability. Nine of the eleven programs include specific options for an RIW, and seven of those nine also include provisions for MTBF guarantees. Seven programs contain potential requirements for logistics support cost commitments or guarantees.

Most of the guarantee requirements are similar among the candidate subsystems. The earlier ARC-164 radio program was the prototype for application of logistics support cost guarantees and the ARN-118 Tacan program was the prototype for the application of long-term RIWs and guaranteed MTBF provisions. Subsequent programs adopted the prototype contract formats. All of these requirements (explicit and implicit) focus attention on the Government's desire to minimize operational support costs and maximize equipment availability through increased equipment reliability and maintainability.

(continued) 1264-01-11370 (Annapolis, Md.: ARINC Research Corp., 1975) for more information about the AFLC cost model and the F-16 LSC provisions.

[1]The LSC commitment is really a guarantee of field reliability and maintainability, to the extent that these items drive the LSC value. The major differences between this commitment and the RIW-MTBF provisions are the risks associated with organic maintenance, the validity of the field measurements, and the protection afforded by the allowable interval associated with the target logistics support cost values.

III

THE WARRANTY INTRODUCTION PROCESS AND CONTRACTOR ENVIRONMENT

Previous IDA research into electronics subsystem acquisition policy and preliminary discussions with both Government personnel and industrial contractors indicate that the impact of the new warranty policies is influenced to a great extent by the characteristics of policy application.[1] The earlier the policies are applied in an equipment development program, the longer time the policies will have to influence the equipment design or development program planning. The contractor response to the policies for warranty application may also be affected by many factors, including (a) the manner in which the warranty requirements are formally applied to the program and (b) the contractor's past exposure to equipment warranties or operational performance guarantees.

A. INTRODUCTION OF WARRANTY REQUIREMENTS

The introduction of warranty requirements was found to be a two-step process consisting of, first, informal discussions between the Government program officers and the equipment contractors and, second, formal introduction of the potential warranty requirements as contract elements. The formal statements of future contract requirements usually surface as draft statements that eventually are refined and incorporated into a formal Request for Quotation (RFQ) or Request for Proposal (RFP).

[1]This was shown to be a key variable of the design-to-cost acquisition policies investigated previously by IDA and reported in C. David Weimer, *The Application of Design-to-Cost Acquisition Policies to Selected Electronics Subsystem Development Programs*, IDA Study S-459 (1975).

Since contractors are able to respond most positively to formal statements of new contract requirements, the IDA research questionnaire was designed to identify the point in the development programs at which the warranty requirements were formalized. Such identification was believed to present a consistent measurement of an event that would precipitate a contractor response, which in turn would reflect a design or development program impact.

Of the eleven candidate programs examined during this study, nine contain explicit mention of future equipment warranty possibilities in their engineering development program RFP. In some instances, such as in the basic F-16 full-scale development RFP, warranty provisions were added as a requirement only in the final versions. Several draft RFPs were prepared and transmitted to the prospective prime contractors and their subcontractors without any mention of RIW possibilities.[1] Inclusion of RIW and guaranteed MTBF requirements came at a point when the contractors had little time to react and consider fully the future implications for the equipment design, the development program plan, and cost.

While the introduction of warranty requirements occurred most frequently as early as the development program RFP, the final negotiation of the specific contract requirements did not usually occur until some time later. The experience of the sixteen questionnaire respondents is illustrated in Figure 3. Six contractors negotiated the terms and conditions of the warranty contract provisions during the negotiations for the combined engineering development and production contracts.[2]

[1] It is believed that the concept of guarantees for logistic support costs was part of the early or initial program planning. The RIW and guaranteed MTBF requirements were added during the final revisions to the RFP.

[2] These engineering development contracts contained fixed-price options for production quantities that essentially specified the terms and conditions for production. There is not to be any separate production RFP award.

Contractor Code	First Formal Indication of Warranty Requirements	Negotiation For Warranty Terms and Conditions
A	Development RFP	Development Contract*
B	Development RFP	Development Contract*
C	Development RFP	Production Contract
D	Development RFP	Production Contract
E	Development RFP	Development Contract*
F	Development RFP	Production Contract
G	Development RFP	Production Contract
H	Development RFP	Production Contract
I	Development RFP	Development Contract*
J	Production RFP	Production Contract
K	Development RFP	Production Contract
L	Development RFP	Development Contract*
M	Development RFP	Production Contract
N	Production RFP	Production Contract
O	Production RFP	Production Contract
P	Development RFP	Development Contract*

*The development contract contained firm options for production units to support a three-year delivery requirement.

Figure 3. WARRANTY REQUIREMENT APPLICATIONS SUMMARY

Seven contractors were formally notified of a potential warranty requirement during the development RFP but were not required to negotiate detailed requirements until the production contract. The remaining three contractors did not formally learn of warranty requirements until the production RFP.[1] The contractor survey shows that most (thirteen out of sixteen) learned of the Government's intention to consider an equipment warranty as a result of the development RFP. However, seven of those contractors did not know what the warranty requirements would ultimately be. And each of these thirteen contractors was developing equipment with option possibilities for warranty exercise rather than firm requirements for warranty incorporation.

B. CONTRACTOR DEVELOPMENT PROGRAM STATUS

The development program status of each candidate contractor was also determined by the questionnaire in an effort to qualify, by present program experience, the responses describing program impact. It was found that seven of the contractors had completed their product development programs at the time of their response (1 June 1976). The other contractors' development programs were from 10-85 percent complete. The average program status of those still in the development stage at the time of their questionnaire response was approximately 50 percent complete.

A correlation of program status and application of warranty requirements is presented in Figure 4. The six contractors who negotiated warranty requirements prior to development contract award could assess and report the warranty impact. Similarly, the seven contractors who finalized the warranty requirements during development could report the impact of the requirements as they were formulated during the development phase. The

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[1]These results relate to formally transmitted warranty requirements or statements of work for potential pricing and bidding.

remaining three contractors were obligated to report the impact that might have occurred had they known prior to the production RFP that warranty provisions were to be priced as an optional contractual requirement.

Timing of Formal Warranty Requirements Application	Number of Contractors	Number of Contractors With Completed Development Programs	Number of Contractors Still In Development
Before Development Contract Award	6	2	4
During the Development Program	7	4	3
At Production Contract Award	3	1	2*

*These two contractors were the only respondents who did not have opportunity to experience and report their actual program warranty impact.

Figure 4. APPLICATION OF WARRANTY REQUIREMENTS AND CURRENT PROGRAM STATUS

C. EQUIPMENT TECHNOLOGICAL STATUS

The design and execution of product development programs depend in large measure on the technical difficulties to be surmounted. Whether the product represents an improvement over predecessor equipment or is a new technological development can also determine the degree of development risk to be managed during the program, as well as the ability of the contractor to predict future field reliability and maintainability from development program test results. Thus, the impact exerted by future requirements for product warranties could easily be enhanced or attenuated, depending on the technical risks and product performance uncertainties to be addressed during development.

The technical status of contractor equipment, as determined by the questionnaire is shown in Figure 5. A majority of the respondents characterized their product as a new technological development rather than a product improvement.[1] Other factors being equal, it is reasonable to expect that these development programs contained a significant amount of technical risk, and by their very nature, little previous product reliability or maintainability data would be directly relevant to efforts to predict equipment operational performance with confidence.

Contractor Code	Development Classification		
	Product Improvement (over previous model)	New Technological Development	Other
A		X	
B		X	
C		X	
D			No Response
E		X	
F		X	
G		X	
H	X		
I		X	
J		X	
K	X		
L		X	
M	X		
N	X		
O		X	
P		X	

Figure 5. SUMMARY OF CONTRACTOR ASSESSMENT OF EQUIPMENT DEVELOPMENT CLASSIFICATION

[1]This response was unexpected because many of the equipment developments that were characterized by the Government program offices as product improvements were not classified as such by the contractor.

D. CONTRACTOR WARRANTY EXPERIENCE

Another factor that could be critical in the warranty application and response is the contractor's previous experience with equipment warranties.[1] We expected that if the contractors had previous experience with the negotiation and execution of multi-year warranties many of the warranty impacts would be easier to identify during succeeding programs.

Responses to our inquiry concerning previous warranty experience indicated that only three of the sixteen respondents had acquired multi-year warranty experience on predecessor equipment. Of the three, only one contractor had relevant military experience. The other two contractors were producing similar equipment for both the military and civilian markets and had experience with the airline warranty environment on the civilian side of their business. However, this experience was not readily available or transferable to the candidate programs because of organizational barriers or differences in equipment operating environment.

These findings reveal that the warranty proposals and the eventual contracts were, except for a small minority, the first contractual exposure most of the contractors had to multi-year warranties. Generally, there was little internal corporate experience with the warranty concept and thus very little basis for adopting a design approach or for structuring a development program using past warranty experience.

E. WARRANTY CONTRACT NEGOTIATION DIFFICULTIES

The research thus far has shown that negotiation of warranty contract provisions occurred throughout the typical

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[1]We were only interested in the special case of multi-year, failure-free repair or maintenance warranties. One-year warranties for correction of deficiencies or defects were not considered part of relevant experience.

development program and, in many cases, was not finalized until the production contract. It was also found that the candidate programs were predominately characterized by the contractors as being new technological developments, rather than product improvements. And finally, the introduction of multi-year warranty provisions was a new experience for most of the candidate contractors. This environment must now be integrated with the negotiation experiences reported by the candidate contractors who had successfully negotiated warranty contracts, or who were currently in the negotiation process.

Based upon our initial contractor interviews, a decision was made to inquire as to which contract areas were the most critical during the warranty negotiation. This approach was adopted in the belief that identification of critical negotiating areas would be positive indicators of changes in equipment design or development planning. Especially when warranty negotiations occurred early in the development program, it was thought that innovations or changes in design and development activities should be observable that would provide greater contractor confidence about achieving the most difficult contractual commitments. Ten typical problem areas, derived from the initial contractor discussions, were presented in the questionnaire and space was provided for additional entries.

Contractor responses to this part of the questionnaire are shown in Table 3. As indicated by the table, twelve of the contractors reported that the measurements of field reliability was a critical area. Closely related to this area is "definition of relevant failures," which ranked second with ten responses. Areas of "warranty price" and equipment "turnaround time" also were critical areas for at least half of the respondents.

Concern about the measurement of actual field reliability is related to identifying failures that can be considered

Table 3. CRITICAL AREAS IDENTIFIED FOR SUCCESSFUL WARRANTY CONTRACT NEGOTIATION

Critical Negotiating Area or Requirement	Contractor Code																Response Total
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
1. Definition of Relevant Failures	X	X		X	X		X			X	X	X	X			X	10
2. Turn-Around Time		X		X	X	X	X			X	X					X	8
3. Consignment Spare Provisions				X	X		X	X		X	X						6
4. Warranty Price		X		X	X	X	X		X	X			X		X		9
5. Measurement of Field Reliability	X	X		X	X	X	X	X		X	X		X	X		X	12
6. ECP Procedures	X			X	X		X				X				X		6
7. Economic Escalation Provisions				X			X						X		X		4
8. Configuration Control Provisions							X			X					X		3
9. Warranty Time Period			X	X	X	X	X			X					X		7
10. Reliability Demonstration and Validation														X		X	2
11. Unverified Failures										X			X				2

relevant. Because of these findings, the design of the equipment can be expected to reflect efforts to identify or verify relevant failures quickly. Also, the design should reflect a concern for accurately measuring equipment operating times. Additional development test time to verify these design features might also be expected.

Turn-around time was of great concern to the contractors because of the penalties that could be imposed if negotiated times were exceeded. Batch shipments of failed units, for example, could disrupt the normal production process, and costly replacement or provision of contingency spares could also be required to maintain a smooth pipeline flow. Our analysis of turn-around time indicates a need for more contractor study of the proposed equipment inspection and repair process, as well as the sources and financial impact of potential delays in turn-around time.

Warranty price was a problem area because price level determines the reliability break-even point for achieving the incentive profit as well as the maximum and total incentive fee available to the contractor over the warranty term.[1] The proper balance of risk and reward is therefore of major concern to all contractors.[2]

F. FINDINGS

This chapter has reported research findings in the areas of warranty requirements application, subsystem technological

[1]This is not to imply an incentive-fee type warranty contract. Incentive profit can be achieved by reducing fixed-price warranty costs below estimated costs.

[2]It is the opinion of the investigators that warranty price negotiations have presented difficulties primarily because the Government's calculation of the warranty "should cost" value does not discount guaranteed equipment reliability values for field operations and does not permit profit or fee levels high enough to compensate for risk.

status, contractor warranty experience, and critical areas of warranty negotiation. These variables, associated with the application of the warranties and the conditions within the contractor environment, are believed to be important considerations when the impact of warranties upon equipment design and development program execution is investigated.

Our research indicates that while most of the contractors were made aware of the Government's intention to consider warranties as a production contract option, the terms and conditions of the warranty were frequently not finalized until the production contract negotiations. Of the subsystem contractors examined in this study, all but two had the opportunity to plan and conduct development programs knowing that future warranty requirements were a possibility.

In response to inquiries about their products' technological status, most contractors reported that they believed that their equipment represented a new technological development as compared with a product improvement over a previous model. To the extent that utilization of advanced technology can be related to technical risk and subsequent warranty risk, this environment can be expected to support risk-identification and minimization activities during design and development. It was also found that most of the contractors did not have past relevant warranty experience that would have increased their perception of risks associated with these agreements and obligations.

The environment of concern over the uncertain timing and definition of warranty requirements, the advanced technological status of the equipment, and the new contractual commitments containing future financial uncertainties, was reflected in the critical areas of warranty negotiation. The definition of relevant failures, measurement of field reliability, warranty

price, and turn-around time proved to be the most difficult areas for final warranty negotiation.[1]

The environment for warranty application was, therefore, found to be contractually, technically, and financially uncertain. This uncertainty will have to be considered when warranty impacts are identified and analyzed.

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[1]Many of the critical areas overlap or are interrelated and bear heavily on negotiation difficulties with warranty price.

IV

THE IMPACT OF WARRANTIES ON CANDIDATE SUBSYSTEM DEVELOPMENT PROGRAMS

The previous chapter documented the application of warranties to the candidate development programs. Based upon the data derived from contractor interviews and the contractor-completed questionnaires, this chapter examines the impact of the warranties on the conduct of the candidate development programs. Section A analyzes the reported impact in terms of the functional elements of a standardized electronics development program. Section B analyzes the warranty requirements that drove the reported program impacts. And Section C analyzes the barriers associated with warranties that prevent greater program impacts from occurring.

A. DEVELOPMENT PROGRAM ELEMENT IMPACTS

1. Summary of Questionnaire Responses

The IDA research questionnaire[1] identified fifty-two functional elements of a typical electronics development program. These elements were organized into thirteen program categories, each of which encompasses from one to ten functional elements. The impact of warranties on development program elements and categories was recorded for the total sample and for various subsets.

The actual warranty impact on candidate program elements was derived from contractor responses to the questionnaire. Contractors were asked to identify those functional program elements that were actually influenced by the existence or

[1] Appendix D.

possibility of a warranty option and to estimate that impact in terms of incremental effort or program scope change. The assumption was that the warranty was to be a priced option and that the usual Government development requirements relating to organic maintenance were also imposed on the program. The choice of response for each functional element was divided into six possibilities, ranging from a moderate decrease in effort to a significant increase in total effort. The contractors were to assume that a "small" increase or decrease represented approximately a 10 percent change, a "moderate" increase or decrease a 20 percent change, and a "significant" increase represented anything over 25 percent additional effort. Table 4 presents a summary of the contractor estimates (sixteen in the total sample) of incremental effort required in each of the development program functional areas as a result of the existence or possibility of a warranty commitment.

As shown in the table, the majority of the responses for each functional element indicated that there had been no warranty-induced changes in the development programs. As an aggregate percentage, two-thirds of the responses were void of change impacts, and a total of 83 percent of the responses indicated an impact of 10 percent or less.

The raw data from the questionnaire responses were further processed to enable the investigators to derive a quantitative measure of development program impact. From this analysis, the program elements receiving the greatest impact could be identified and ordered by decreasing (or increasing) impact magnitude.[1] The data processing consisted of a valuation technique whereby,

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[1]A difficulty inherent in this analytical approach was recognized to be the non-homogeneity of the program element weights among the candidate programs, as well as the relative weights, measured by cost or effort expended, between various major and minor program elements within any one program. The possibilities of these sources of potential bias were considered. The reader should recognize this limitation whenever extrapolations of these findings are made to other, non-typical programs.

Table 4. ACTUAL RIW IMPACT ON CANDIDATE DEVELOPMENT PROGRAMS

Development Program Elements	Number of Contractor Responses					
	Moderate Decrease	Small Decrease	No Change	Small Increase	Moderate Increase	Significant Increase
DESIGN						
Circuit			11	3	2	
Card and Board			10	3	2	1
Module			11	3	1	1
SRA			11	3	1	1
LRU or FLU			10	3	3	
System Architecture			11	2	2	1
Built-In Test			10	3	1	2
Test Equipment			10	2	1	3
Ground Support Equipment	1	1	13	1		
Production Tooling			12	1	3	
ANALYSIS						
Thermal			9	3	2	2
Stress			11	3	2	
EMC			14	1	1	
Environment			10	2	3	1
Failure-Mode-Effects			8	3	5	
Reliability			6	3	4	3
Maintainability			8	3	2	3
Producibility			12	2	1	1
Optimum Repair Level			10	1	3	2
Cost-Performance			11	2	3	
MATERIALS AND PURCHASED PARTS						
Part Selection			8	5	3	
Vendor Screening			9	5		2
Cost Estimating and Pricing			11	3	1	1
PROTOTYPE MANUFACTURE						
Component Procurement			13	2	1	
Card or Board Assembly			14	2		
Module Assembly			13	3		
Box or Chassis Assembly			14	2		
Functional Test and Checkout			10	6		
EQUIPMENT TEST						
Part/Component Accept. Test			13	1	1	1
Breadboard Tests			13	2		1
Brassboard Tests			11	3	1	1
Equip. Performance Demo.			12		2	2
Equipment Environmental Tests			12	1	1	2
Equipment Reliability Tests			9	3	2	2
QUALITY ASSURANCE						
Quality Engineering			11	3	2	
Inspection			11	4		1
In-Process Monitoring			13	1	1	1
Test Monitoring			9	3	3	1
PROGRAM MANAGEMENT						
Cost Tracking			9	3	3	1
FINANCIAL MANAGEMENT						
Production Cost Analysis			10	1	4	1
Economic Escalation Analysis			12	2	1	1
Life-Cycle Cost Analysis			8	2	4	2
Program Financial Control			11	2	3	
PRODUCT SUPPORT						
Spares Requirements			12	2	1	1
Container Design and Analysis			11	5		
STE/AGE Design and Analysis			10	3	2	1
Logistics Planning			7	4		5
PRODUCTION ENGINEERING						
Production Analysis			11	4		1
Manufacturing Analysis			11	4	1	
VALUE ENGINEERING			13	2	1	
DATA AND REPORTS			10	2	3	1
CONTRACT MANAGEMENT			9	3	3	1
Total Number of Contractor Responses	1	1	558	135	86	51
Percent of Total Response	0.12%	0.12%	67.07%	16.22%	10.34%	6.13%

based upon the guidelines given to the contractors, a small increase/decrease was assigned a value of +10/-10, a moderate increase/decrease was assigned a value of +20/-20, a significant (greater than 25 percent) increase was arbitrarily assigned a value of +30, and no change was given a value of 0.[1]

Table 5 presents the results of the weighted valuation of the program elements. This processing results in a measured average impact for the aggregate programs of +5.48 percent within a range of 0 to 19.60 percent. The average increase for a typical program effort was, therefore, estimated by the contractors to be about 5.5 percent, with individual programs receiving from 0 percent to almost a 20 percent increase in effort. The weighting system also illustrates those individual program elements and groupings of program elements that are responsible for the major changes in development program effort.

2. Analysis of Impacts on Program Elements

a. Design

The design task of the development program was anticipated to be an area in which a major impact would be recorded. However, the data show that the average impact reported for this category was only 5 percent. Seven contractors reported no design impact whatever, and two contractors reported only a small impact. Only three contractors estimated greater than a 10 percent increase in the design effort; however one of those contractors, Contractor B, felt that the warranty option caused a 24 percent increase in design effort. The greatest average impacts within the design function were reported in areas of test equipment design, built-in test design, and card and board design.[2]

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[1]If a value of 50 were assigned instead of 30, the results of the responses would be altered by one percentage point.

[2]Note the correlation with concerns during negotiations about identifying and isolating failures at the organizational level.

Table 5. WARRANTY IMPACT ON CANDIDATE PROGRAMS

Development Program Element	PERCENT CHANGE IN DEVELOPMENT PROGRAM EFFORT — CONTRACTORS																Total	Average
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P		
DESIGN*	*50*	*240*	*0*	*10*	*0*	*0*	*150*	*0*	*0*	*0*	*40*	*70*	*10*	*100*	*0*	*130*	*800*	*5.00*
Circuit	0	20	0	0	0	0	20	0	0	0	0	10	0	10	0	10	70	4.38
Card and Board	0	30	0	0	0	0	20	0	0	0	10	20	0	10	0	10	100	6.25
Module	0	30	0	0	0	0	20	0	0	0	10		0	10	0	10	80	5.00
SRA	0	30	0	0	0	0	20	0	0	0	0	10	0	10	0	10	80	5.00
LRU or FLU	10	20	0	0	0	0	20	0	0	0	0	10	0	10	0	20	90	5.63
System Architecture	10	20	0	0	0	0	20	0	0	0	0	0	0	10	0	30	90	5.63
Built-in Test	20	30	0	10	0	0	0	0	0	0	10	0	0	10	0	30	110	6.88
Test Equipment	30	30	0	0	0	0	30	0	0	0	10	0	0	10	0	20	130	8.13
Ground Support Equipment	-20	10	0	0	0	0	0	0	0	0	0	0	0	0	0	-10	-20	-1.25
Production Tooling	0	20	0	0	0	0	0	0	0	0	0	20	10	20	0	0	70	4.38
ANALYSIS	*150*	*230*	*70*	*0*	*0*	*0*	*150*	*40*	*0*	*0*	*70*	*80*	*40*	*80*	*0*	*200*	*1110*	*6.94*
Thermal	20	30	0	0	0	0	10	10	0	0	0	20	10	0	0	30	130	8.13
Stress	0	20	0	0	0	0	10	10	0	0	0	0	10	0	0	20	70	4.38
EMC	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	10	30	1.88
Environment	10	20	0	0	0	0	20	0	0	0	0	20	0	10	0	30	110	6.88
Failure-Mode-Effects	20	20	0	0	0	0	20	0	0	0	10	10	10	20	0	20	130	8.13
Reliability	30	20	20	0	0	0	30	20	0	0	10	10	10	20	0	30	200	12.50
Maintainability	20	30	30	0	0	0	20	0	0	0	10	10	0	10	0	30	160	10.00
Producibility	0	30	0	0	0	0	0	0	0	0	10	10	0	20	0	0	70	4.38
Optimum Repair Level	30	20	20	0	0	0	30	0	0	0	10	0	0	0	0	20	130	8.13
Cost-Performance	20	20	0	0	0	0	10	0	0	0	20		0	0	0	10	80	5.00
MATERIALS AND PURCHASED PARTS	*30*	*60*	*0*	*0*	*0*	*0*	*50*	*50*	*0*	*0*	*30*	*10*	*0*	*40*	*0*	*30*	*300*	*6.25*
Part Selection	10	20	0	0	0	0	20	10	0	0	10	10	0	10	0	20	110	6.88
Vendor Screening	10	30	0	0	0	0	30	10	0	0	10	0	0	10	0	10	110	6.88
Cost Estimating and Pricing	10	10	0	0	0	0	0	30	0	0	10	0	0	20	0	0	80	5.00
PROTOTYPE MANUFACTURE	*10*	*10*	*0*	*0*	*0*	*0*	*60*	*10*	*0*	*0*	*10*	*10*	*0*	*10*	*0*	*50*	*170*	*2.13*
Component Procurement	0	0	0	0	0	0	20	0	0	0	0	10	0	0	0	10	40	2.50
Card or Board Assembly	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	10	20	1.25
Module Assembly	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0	10	30	1.88
Box or Chassis Assembly	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	10	20	1.25
Functional Test and Checkout	10	10	0	0	0	0	10	0	0	0	10		0	10	0	10	60	3.75
EQUIPMENT TEST	*20*	*100*	*0*	*0*	*0*	*0*	*180*	*0*	*0*	*0*	*20*	*20*	*10*	*40*	*0*	*120*	*510*	*5.31*
Part/Component Accept. Test	0	20	0	0	0	0	30	0	0	0	0	0	0	0	0	10	60	3.75
Breadboard Tests	0	10	0	0	0	0	30	0	0	0	0	0	0	0	0	10	50	3.13
Brassboard Tests	0	20	0	0	0	0	30	0	0	0	10	0	10	0	0	10	80	5.00
Equip. Performance Demo.	0	20	0	0	0	0	30	0	0	0	0	0	0	20	0	30	100	6.25
Equipment Environmental Tests	0	20	0	0	0	0	30	0	0	0	0	10	0	0	0	30	90	5.63
Equipment Reliability Tests	20	10	0	0	0	0	30	0	0	0	10	10	0	20	0	30	130	8.13
QUALITY ASSURANCE	*10*	*110*	*0*	*0*	*0*	*0*	*20*	*10*	*0*	*0*	*40*	*10*	*0*	*40*	*0*	*70*	*310*	*4.84*
Quality Engineering	0	20	0	0	0	0	0	0	0	0	10	10	0	10	0	20	70	4.38
Inspection	0	30	0	0	0	0	0	0	0	0	10	0	0	10	0	10	60	3.75
In-Process Monitoring	0	30	0	0	0	0	0	0	0	0	10	0	0	0	0	20	60	3.75
Test Monitoring	10	30	0	0	0	0	20	10	0	0	10	0	0	20	0	20	120	7.5
PROGRAM MANAGEMENT	*30*	*20*	*10*	*10*	*0*	*0*	*0*	*0*	*0*	*0*	*10*	*0*	*0*	*20*	*0*	*20*	*120*	*7.5*
Cost Tracking	30	20	10	10	0	0	0	0	0	0	10	0	0	20	0	20	120	7.5
FINANCIAL MANAGEMENT	*70*	*80*	*20*	*0*	*0*	*0*	*10*	*60*	*0*	*0*	*60*	*0*	*0*	*80*	*0*	*50*	*430*	*6.72*
Production Cost Analysis	20	20	0	0	0	0	0	20	0	0	10	0	0	30	0	20	120	7.5
Economic Escalation Analysis	0	20	0	0	0	0	0	30	0	0	10	0	0	10	0	0	70	4.38
Life-Cycle Cost Analysis	30	20	20	0	0	0	10	10	0	0	20	0	0	30	0	20	160	10.00
Program Financial Control	20	20	0	0	0	0	0	0	0	0	20	0	0	10	0	10	80	5.00
PRODUCT SUPPORT	*100*	*60*	*0*	*30*	*30*	*0*	*20*	*50*	*0*	*0*	*40*	*0*	*0*	*20*	*0*	*60*	*410*	*6.41*
Spares Requirements	30	20	0	0	0	0	0	0	0	0	10	0	0	10	0	0	70	4.38
Container Design and Analysis	10	10	0	0	0	0	0	10	0	0	10	0	0	0	0	10	50	3.13
STE/AGE Design and Analysis	30	20	0	0	0	0	10	10	0	0	10	0	0	0	0	20	100	6.25
Logistics Planning	30	10	0	30	30	0	10	30	0	0	10	0	0	10	0	30	190	11.85
PRODUCTION ENGINEERING	*0*	*50*	*0*	*0*	*0*	*0*	*0*	*20*	*0*	*0*	*20*	*0*	*0*	*20*	*0*	*20*	*130*	*4.06*
Producibility Analysis	0	30	0	0	0	0	0	10	0	0	10	0	0	10	0	10	70	4.38
Manufacturing Analysis	0	20	0	0	0	0	0	10	0	0	10	0	0	10	0	10	60	3.75
VALUE ENGINEERING	*0*	*10*	*0*	*0*	*0*	*0*	*20*	*0*	*0*	*0*	*10*	*0*	*0*	*0*	*0*	*0*	*40*	*2.50*
DATA AND REPORTS	*20*	*30*	*20*	*0*	*0*	*0*	*0*	*10*	*0*	*0*	*10*	*0*	*0*	*0*	*0*	*20*	*110*	*6.88*
CONTRACT MANAGEMENT	*20*	*20*	*10*	*0*	*0*	*0*	*0*	*30*	*0*	*0*	*10*	*0*	*0*	*20*	*0*	*10*	*120*	*7.50*
TOTAL	*510*	*1020*	*130*	*50*	*30*	*0*	*660*	*280*	*0*	*0*	*370*	*200*	*60*	*470*	*0*	*780*	*4560*	
AVERAGE (PERCENT)**	*9.80*	*19.60*	*2.50*	*0.96*	*0.58*	*0*	*12.69*	*5.38*	*0*	*0*	*7.12*	*3.85*	*1.15*	*9.04*	*0*	*15.00*		*5.48*

*Italicized numbers for each major heading are totals of subelements.

**The average impact is based on the average of all subelements. Because of rounding, the average of the major element totals is 5.54 percent.

b. Analysis

The analysis portion of the development program was also expected to register a large warranty impact. However, the reported results were similar to those recorded for design.

Of the sixteen contractors, six reported no impact on the analysis function. The highest impacts approached 25 percent, as with the design functions. Typically, contractors who experienced an impact in analysis also reported an impact in design. It was not surprising that the areas of greatest impact were reliability analysis and maintainability analysis. Thermal analysis, failure-mode-effects analysis, and optimum repair level analysis also showed significant impacts. In most cases, the analysis impact was greater than the design impact, averaging 6.9 percent vis-à-vis 5.0 percent for design.

c. Materials and Purchased Parts

This area of the development program also was reported to have experienced a higher-than-average impact of 6.25 percent. These findings were not surprising (except for the generally low level), since much of the reliability demonstrated by the space program has been claimed to have been derived from improved parts and materials control. It was anticipated that concern over future equipment reliability would be revealed strongly in the materials or purchased parts specifications.

d. Prototype Manufacture

This program area showed a very small impact (approximately a 2 percent average increase); eight contractors reported no impact. From this response, it is obvious that despite the contractor's desire for more prototype validation, additional prototypes were not being built in the current programs as a result of warranty considerations.

e. Equipment Test

Half of the sixteen contractors indicated no impact in this program area; however, two contractors reported maximum impacts ("significant increase") for many of the equipment test elements. The average impact on the equipment test function was approximately a 5 percent increase; the highest impact was reported for reliability testing.

f. Quality Assurance

This was another area in which additional effort resulting from warranty considerations was expected to be evident. However, as Table 5 illustrates, an aggregate impact of only 4.8 percent was reported. Half of the contractors reported no additional effort in this category.

g. Program Management

Program management similarly received added emphasis from only about half of the reporting contractors (seven). However, the impact reported by those who were affected was split between a moderate and a small effect, resulting in a group average of those reporting an impact of 17 percent. The overall sample impact (counting those reporting no impact) was 7.5 percent.

h. Financial Management

Although half of the sixteen contractors indicated no impact on financial management, the range of impacts went up to 20 percent for two of the contractors. Life-cycle cost analysis showed a 10 percent increase in impact and production cost analysis showed a 7.5 percent increase.

i. Product Support

Seven contractors reported no impact on product support, but one contractor reported a 20 percent increase. There was

almost a 12 percent average increase in effort in the logistics planning function.

j. Other Program Elements

Other program elements examined for a warranty impact were production engineering, value engineering, data and reports, and contract management. Data and reports and contract management were the areas of highest reported impact with 6.9 and 7.5 percent, respectively. It should be noted that these two elements are not direct contributors to equipment design reliability.

3. Combined Development Program Impact

Figure 6 is a histogram showing the average warranty impact for the thirteen major categories into which the functional program elements were grouped. As discussed above, the highest impacts were reported in the areas of program management, financial management, contract management, analysis, and data and reports.

Because many contractors reported no measurable impact in many program elements, an analysis was made to quantify the program element impact based upon only those contractors who reported an impact.[1] The results of this analysis are compared with the full aggregate sample analysis in Table 6 below.

The results presented in Table 6 demonstrate that, while the aggregate impact for all contractors responding to the questionnaire was about 5 percent, those program elements that received a warranty impact other than zero combined to give an

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[1]No correlation could be found between the contractor impact response and equipment application, Service management, or equipment type. For example, it was expected that contractors who were merely developing a "product improvement" would report a smaller impact than the others. However, three of the four contractors who characterized their equipment as a "product improvement" (K, N and H) reported impacts in at least nine of the thirteen program categories. A full discussion of these results and analyses is presented in Chapter V.

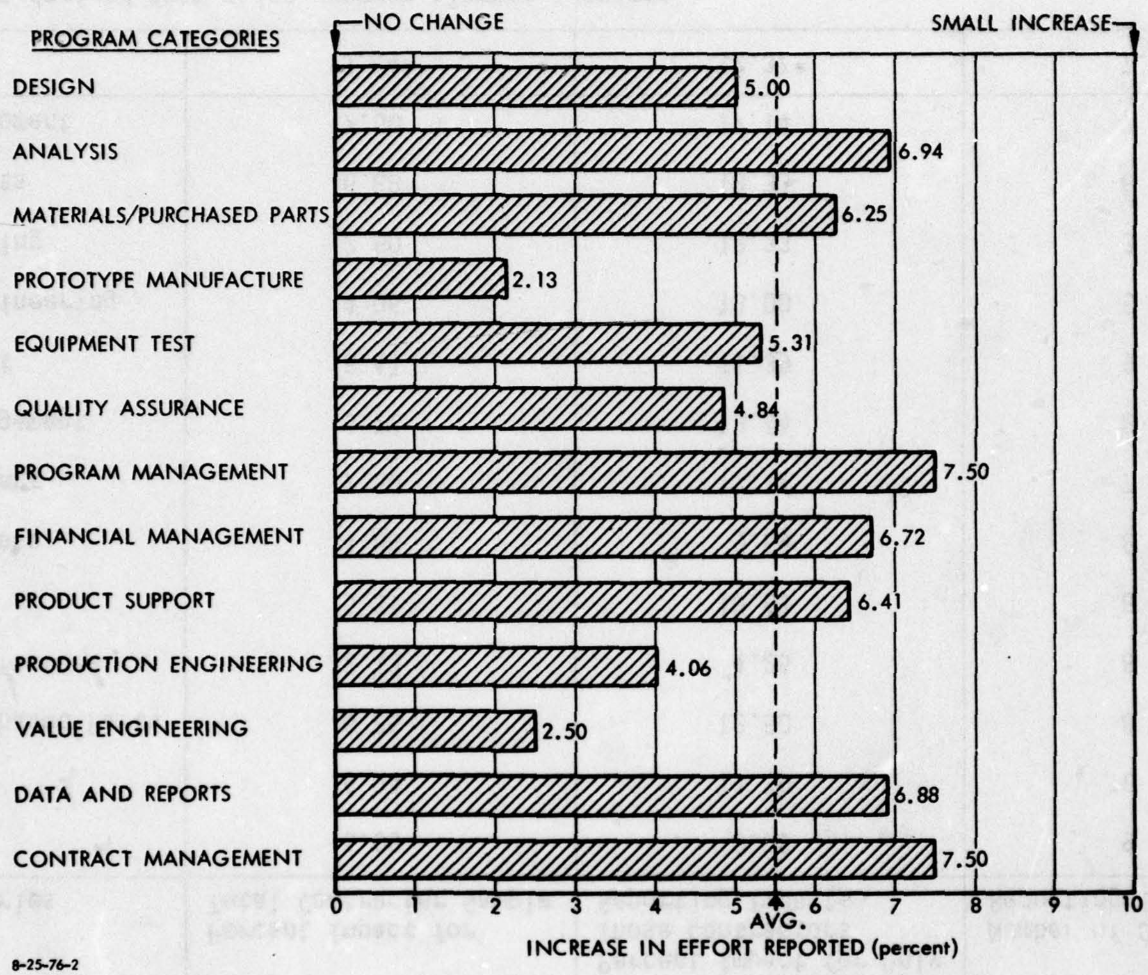

Figure 6. REPORTED IMPACT UPON DEVELOPMENT PROGRAM BY MAJOR PROGRAM CATEGORIES

Table 6. COMPARISON OF REPORTED WARRANTY IMPACTS

Program Categories	Percent Impact for Total Contractor Sample	Percent Impact for Only Those Contractors Reporting Impacts	Number of Contractors Reporting Impacts
Design	5.00	8.89	9
Analysis	6.94	11.10	10
Materials/Purchased Parts	6.25	12.50	8
Prototype Manufacture	2.13	4.25	8
Equipment Test	5.31	10.63	8
Quality Assurance	4.84	9.69	8
Program Managment	7.50	17.14	7
Financial Management	6.72	13.44	8
Product Support	6.41	11.39	9
Production Engineering	4.06	13.00	5
Value Engineering	2.50	13.33	3
Data and Reports	6.88	18.33	6
Contract Management	7.50	17.14	7
Average	5.54*	12.37*	7.4

*Average values derived from major program element averages.

average development program impact of 12.4 percent. The program categories also change in relative importance. In the total aggregate sample, the highest impacts were reported in program management, contract management, analysis, data and reports, and financial management. The major impacts for just those elements receiving impacts were also observed to include program management, financial management, and contract management. However, data and reports now has the highest reported impact at 18.33 percent, and production engineering, value engineering, and materials/purchased parts have been added to financial management as leading areas of warranty impact.

Table 7 illustrates the reported aggregate impact on individual development program elements in terms of an ordered listing by impact magnitude. Note the relative position of the design-related program elements (identified with an asterisk), which indicates that design efforts are being affected by the warranty environment.

B. WARRANTY REQUIREMENTS DRIVING PROGRAM IMPACTS

While this subject area was not explicitly addressed in the research questionnaire, in our interviews with contractors we attempted to identify some of the principal warranty requirements responsible for the reported development program impacts. We found that most requirements could be categorized into one of two conceptual classes. The first class consists of those requirements that are contractually imposed and that affect equipment features or development or production program content.

Some of the requirements identified in this class are listed below:

- Display of warranty information on equipment
- Labels on unit for recording installation and removal date
- Seals

Table 7. RELATIVE IMPACT UPON INDIVIDUAL PROGRAM ELEMENTS

Development Program Elements	Percent Change in Development Program Effort
Reliability Analysis*	12.50
Logistics Planning	11.85
Life-Cycle Cost Analysis	10.00
Maintainability Analysis*	10.00
Equipment Reliability Tests	8.13
Failure-Mode-Effects Analysis*	8.13
Test Equipment Design	8.13
Thermal Analysis*	8.13
Optimum Repair Level Analysis	8.13
Production Cost Analysis	7.50
Cost Tracking	7.50
Contract Management	7.50
Test Monitoring	7.50
BITE Design*	6.88
Environmental Analysis*	6.88
Part Selection*	6.88
Vendor Screening	6.88
Data and Reports	6.88
Card/Board Design*	6.25
Equipment Performance Demo. Test	6.25
STE/AGE Design & Analysis*	6.25
Equipment Environmental Tests	5.63
System Architecture Design*	5.63
LRU/FLU Design*	5.63
Module Design*	5.00
SRA Design*	5.00
Cost Estimating & Pricing	5.00
Program Financial Control	5.00
Cost-Performance Analysis	5.00
Brassboard Tests	5.00
Economic Escalation Analysis	4.38
Quality Engineering	4.38
Producibility Analysis	4.38
Circuit Design*	4.38
Spares Requirements	4.38
Producibility Analysis (Production Engr'g.)	4.38
Stress Analysis*	4.38
Production Tooling Design	4.38
Quality Assurance Inspection	3.75
Manufacturing Analysis	3.75
Functional Test/Checkout Proto. Man.	3.75
In-Process Quality Assur. Monitoring	3.75
Part/Component Accept. Tests	3.75
Container Design & Analysis	3.13
Breadboard Tests	3.13
Value Engineering	2.50
Component Procurement-Proto. Man.	2.50
Module Assembly-Proto. Man.	1.88
EMC Analysis	1.88
Box/Chassis Assy.-Proto. Man.	1.25
Card/Board Assy.-Proto. Man.	1.25
Ground Support Equip. Design	-1.25
AVERAGE	5.48

*Equipment Design-Related Program Elements

- Elapsed-time indicators
- Data and reports
- ECP and configuration control procedures
- Bonded storerooms
- Warranty repair facility.

The second class of warranty requirements consists of specified equipment or contractor performance parameters that directly influence the achieved equipment reliability, maintainability, or availability. These also are variables that can be directly influenced by contractor trade-offs during the design and development process. Examples of this class of warranty requirements include:

- Guaranteed MTBF (mean time between failures)
- RTOK (retest) OK)
- Average MTTR (mean time to repair)
- CTR (cost to repair)
- Agreed TAT (turn-around time) without penalties
- ECP costs.

The requirements in the second class act in concert such that the classical trade-off between MTBF and MTTR is further complicated by cost penalties associated with required TATs and a desire to minimize the number of RTOKs. These requirement considerations, for example, could be expected to lead to increased effort on many of the development program elements. In the general category of design, we could expect increased effort on system architecture to investigate various circuit partitioning schemes and on BITE design to develop go/no-go tests and to enhance fault isolation.[1] In the area of design analysis, additional efforts in reliability and maintainability analysis are

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[1]Reducing cost-to-repair, mean time to repair, RTOKs, and turn-around time. Specific design impacts reported for candidate equipment will be discussed in Chapter VI.

often needed to achieve the appropriate trade-offs. The MTBF could also be increased by improving inherent reliability through upgraded parts or more vendor screening. An increased effort in prototype manufacturing and equipment test might lead to better information on such parameters as MTBF, MTTR, and CTR. Efforts in product support definitely affect the MTTR and TAT parameters. Efforts in production engineering can indirectly affect the achieved field reliability of the equipments. Finally, other program impacts of a financial, contractual, or managerial nature can stem from the increased levels of direct program activity.

The two classes of warranty requirements also interact. For example, seals and elapsed-time indicators must be analyzed, designed, purchased or manufactured, and tested. And bonded storerooms and contractor repair facilities must be planned along with their appropriate spares inventories and test equipment.

It can be seen from the above discussion that although there can be many impacts stemming from the warranty requirements, the specific cause-effect relationships are lost in overlapping influences. Nevertheless, it is clear that the warranty requirements are collectively responsible for numerous impacts on the candidate development programs.

C. IMPACT BARRIERS

Our initial exploratory interviews with the contractors convinced us that, while marginal impacts occurred as a result of current or recent development program warranty requirements, the potential for more significant impacts was very great. These beneficial impacts, in terms of emphasizing reliability and maintainability during design and development, were being inhibited or prevented by program variables and contract requirements that effectively prevented contractors from taking those

actions they believed to be in the best interests of both parties. Some of the basic barriers were identified during the initial interviews and were used to structure the questionnaire. Other barriers were identified by the responses to specific questions in the questionnaire.[1]

1. Primary Barriers

The primary barriers identified during the initial interviews were--

(a) The uncertainty of future warranty option terms, conditions, and other details during engineering development.

(b) The uncertainty associated with the option status of the warranty.

(c) Product and process specification rigidities that prevented contractor design and development program flexibility.

In several development programs, the specific terms and conditions of the warranty had not been defined even though the programs were well into engineering development. Because of this uncertainty, the contractor lacked the motivation to institute signficant changes in design and development. Contractors reported that had these requirements been known earlier, the warranty impacts on the design and development program could have been greater.

Contractors also reported that the option status of warranties was perhaps the most signficant barrier to increased warranty impacts. The uncertainty as to whether or not the Government would eventually exercise the option led to compromises in equipment design and to doubts concerning the Government's credibility for warranty application. The basic

[1]See questions no. 2 and page D-12 and no. 3 on page D-13 of the questionnaire, Appendix D.

requirements of the contract still required a design for organic maintenance--any changes to the design to enhance contractor maintenance were therefore considered cautiously.

Contractors also indicated that there were conflicts between the objectives of warranties and the application of some military specifications to their equipment. They reported that the inherent guarantee of the warranty superseded the requirement for many of the usual equipment design and process specifications. They stated that if they were allowed greater freedom to design and develop the equipment, development program impacts resulting from warranty requirements would be much higher.

These three primary barriers were judged to be fundamental determinants of warranty impact and were established as major conditions for potential impact analysis. The effects of removing these barriers were subsequently investigated in the questionnaire. The results of that investigation are presented in Chapter V.

2. Additional Barriers

Table 8 presents the results of our inquiry into additional barriers that had not been surfaced in the initial contractor interviews. It is apparent from the reported responses that there are four other major constraints to warranty impacts. These are (1) development funding, (2) development schedule, (3) unit-production cost goal, and (4) performance specifications. In general, these variables represent the primary degrees of freedom available to the development contractors.

Discussions with contractor personnel revealed that the development programs for their electronics subsystems continue to be time and funding constrained.[1] Programs are planned to

[1]This was also true for other programs and contractors investigated during previous IDA Design-to-Cost research.

match major prime equipment delivery schedules and total funds available. Design iterations and additional test programs to give contractors greater confidence in their product performance are casualties of forces exerted by time, funds, and marketing pressures.[1] Unit-production goals, set prior to development, also present barriers to changes in design that would enhance reliability. This is particularly the case when the introduction of warranty considerations occurs after the preliminary design reviews have been accomplished. At this point, the design may already be optimized for production cost rather than reliability assurance.

Table 8. BARRIERS TO DESIGN AND DEVELOPMENT IMPACT

Barrier Candidates	Frequency of Response		
	Minor Constraint	Major Constraint	Total
Development Funding	3	13	16
Development Schedule	5	9	14
Unit Production Cost Goal	6	7	13
Performance Specifications	9	2	11
Reliability Goals	5	2	7
Reprocurement Data Rights	3	4	7
Source Selection Criteria	4	3	7
Part and Process Specifications	4	2	6
Report Requirements	2	1	3
Handbook Changes	0	2	2
Reliability Demonstration	1	0	1
Physical Design	0	1	1
Warranty Terms & Conditions	0	1	1
"Traditionalism" Attitude	0	1	1
Support Equip. Changes	0	1	1
Organic Maintenance Requirement	0	1	1
Limited Field Testing	0	1	1

[1]An important point. No competitive contractor is very willing to admit that he needs more time and money to gain confidence that he can meet (guarantee) the performance specifications for the candidate equipment. Thus, quite often it was observed that these activities were performed using company funds when the contractor believed that the warranty would actually be implemented.

The contractors were also asked to identify the most critical barrier from among their responses shown in Table 8. Their assessment follows the pattern established by the frequency of response, as illustrated in Table 9. The contractors believed that their programs needed more effort (in areas we will subsequently identify) to ensure a greater probability of achieving the reliability guarantees. This effort would require more money and development time. Performance and unit-production cost goal requirements presented additional barriers, which were viewed as being relatively independent of the funding and schedule restrictions.[1]

Table 9. BARRIER RESPONSE ANALYSIS

Reported Barrier	Ranking by Frequency	Ranking by Importance to Contractors
Development Funding	1	1
Development Schedule	2	2
Unit-Production Cost Goal	3	4
Performance Specifications	4	3

D. FINDINGS

The analysis of the contractor interviews and the questionnaire responses led to the following major findings concerning the impact of warranties on the current candidate development programs.

[1]There apparently is an estimated unit-production cost difference between a design that is *proposed* to meet reliability specifications and a design that will be *guaranteed* to meet reliability specifications.

1. Development Program Impact

The reported impact of warranty considerations on the candidate programs was, on the average, small--the aggregate impact was a 5.5 percent increase in overall effort. For the total sample, the greatest impacts were recorded in the functional areas of program, financial, and contract management, analysis, and data and reports.

An analysis of individual candidate programs and program elements indicated a dual impact distribution; approximately half of the sample indicated some impact. Those contractors reporting an impact indicated an average increase in program effort of 12.4 percent. These impacts also were reported in the functional areas of data and reports and contract, program, and financial management.

2. Requirements Driving Program Impacts

A number of warranty requirements were identified as driving the program impacts. Those requirements were divided into two groups: those relatively fixed because of contractual requirements; and those that directly influence the reliability and maintainability parameters of the equipment.

3. Barriers to Program Impacts

Many important barriers to changes in the equipment design or the development programs were identified during our investigations. Primary barriers were (a) uncertainty of warranty requirements, (b) uncertainty of warranty option decisions, and (c) rigid product and process specifications. Additional barriers reported by the contractors were lack of adequate development funds, constrained development schedules, conflicting unit-production cost and reliability goals, and performance specifications.

V

POTENTIAL IMPACT OF WARRANTIES ON CANDIDATE DEVELOPMENT PROGRAMS

As reported in Chapter IV, our research led to the identification of three primary barriers to achieving beneficial design and development program impacts. Accordingly, this chapter examines the potential warranty impacts if the three primary barriers were removed.

The first condition examined is the situation in which the terms and conditions of the warranty option have been negotiated (except for price) at the beginning of the engineering development program. The second condition eliminates the option status from the first condition--it is known at the outset of engineering development that the equipment will eventually be procured with a warranty and that Service organic maintenance will not be implemented, at least for several years after production deliveries begin. The third condition involves the additional feature of specification relief--e.g., all design, performance, and process specifications and requirements are flexible and negotiable except for critical performance, cost, and reliability requirements.[1]

A. POTENTIAL PROGRAM IMPACTS AND WARRANTY DECISIONMAKING

This section compares the *actual* estimated development program impacts reported by the contractors for their current programs with two alternate conditions: (1) the impact if warranty terms and conditions were known at the *beginning* of

[1]This condition is similar to that which is conceptually planned for design-to-cost acquisitions.

engineering development, and (2) the impact if the warranty were a *firm* contractual commitment.[1]

1. Major Program Categories

Tables 10 and 11 present the weighted warranty impacts, as compiled from the contractor questionnaires, for the *beginning* and *firm* conditions.[2]

The average impact, weighted over all development program categories and measured in terms of a percentage increase in effort, climbs from a value of approximately 5.5 percent for the *actual* warranty conditions examined in Chapter IV to an estimated value of 8.2 percent if the terms and conditions were known at the *beginning* of engineering development, and to a value of approximately 10.5 percent if the RIW requirements were not an option but *firm*.

The aggregate impact ratio of *beginning* to *actual* is approximately 1.5 (8.2:5.5); the ratio of *firm* to *beginning* is approximately 1.3 (10.5:8.2). In other words, the estimated increase in impact under the *beginning* conditions is 50 percent greater than the *actual* reported increase in impacts. Further, the *firm* condition impact is another 30 percent greater. The *firm* condition impact is thus 90 percent greater than the *actual* impact (10.5:5.5 = 1.9). The development program impact leverage that can then be attributed to these conditions is thought to be significant.[3]

[1]For discussion purposes, the three warranty requirement conditions described in this paragraph will be referred to in abbreviated form as *actual, beginning,* and *firm.*

[2]Table 5 (Chapter IV) presented similar data for the warranty impact actually experienced during the candidate programs.

[3]The term "leverage" is used throughout this chapter to refer to the relative *increase in impact or impact multiplier* that is attributable to warranty-related decisions made earlier in the acquisition process.

Table 10. WARRANTY IMPACT IF OPTION TERMS AND CONDITIONS WERE KNOWN AT BEGINNING OF ENGINEERING DEVELOPMENT

DEVELOPMENT PROGRAM ELEMENT	PERCENT CHANGE IN DEVELOPMENT PROGRAM EFFORT																	
	CONTRACTORS																Total	Average
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P		
DESIGN*	*50*	*240*	*0*	*10*	*0*	*120*	*150*	*80*	*0*	*90*	*90*	*70*	*30*	*100*	*110*	*130*	*1270*	*7.94*
Circuit	0	20	0	0	0	10	20	10	0	0	10	10	10	10	0	10	110	6.88
Card and Board	0	30	0	0	0	20	20	10	0	0	20	20	10	10	0	10	150	9.38
Module	0	30	0	0	0	20	20	20	0	0	20	0	10	10	20	10	160	10.00
SRA	0	30	0	0	0	20	20	10	0	0	10	10	10	10	20	10	150	9.38
LRU or FLU	10	20	0	0	0	0	20	0	0	20	10	10	10	10	10	20	140	8.75
System Architecture	10	20	0	0	0	0	20	10	0	20	10	0	10	10	10	30	150	9.38
Built-in Test	20	30	0	10	0	0	0	0	0	20	10	0	10	10	20	30	160	10.00
Test Equipment	30	30	0	0	0	30	30	20	0	0	0	0	-20	10	20	20	170	10.63
Ground Support Equipment	-20	10	0	0	0	20	0	0	0	10	0	0	-20	0	10	-10	0	0
Production Tooling	0	20	0	0	0	0	0	0	0	20	0	20	0	20	0	0	80	5.00
ANALYSIS	*150*	*230*	*70*	*0*	*0*	*40*	*100*	*170*	*0*	*110*	*100*	*80*	*0*	*80*	*160*	*200*	*1490*	*9.31*
Thermal	20	30	0	0	0	0	0	30	0	10	0	20	0	0	10	30	150	9.38
Stress	0	20	0	0	0	0	0	30	0	10	0	0	0	0	10	20	90	5.63
EMC	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	10	30	1.88
Environment	10	20	0	0	0	0	10	30	0	0	0	20	0	10	30	30	160	10.00
Failure-Mode-Effects	20	20	0	0	0	10	10	0	0	20	2C	10	10	20	30	20	190	11.88
Reliability	30	20	20	0	0	20	20	30	0	30	20	10	10	20	30	30	290	18.13
Maintainability	20	30	30	0	0	0	20	20	0	20	20	10	-10	10	10	30	210	13.13
Producibility	0	30	0	0	0	0	0	20	0	0	10	10	0	20	10	0	100	6.25
Optimum Repair Level	30	20	20	0	0	10	30	0	0	0	10	0	-10	0	20	20	150	9.38
Cost-Performance	20	20	0	0	0	0	10	10	0	20	20	0	0	0	10	10	120	7.50
MATERIALS AND PURCHASED PARTS	*30*	*60*	*0*	*0*	*0*	*30*	*50*	*60*	*0*	*30*	*60*	*10*	*-20*	*40*	*30*	*30*	*410*	*8.54*
Part Selection	10	20	0	0	0	10	20	20	0	10	20	10	-10	10	10	20	150	9.38
Vendor Screening	10	30	0	0	0	10	30	10	0	10	20	0	-10	10	10	10	140	8.75
Cost Estimating and Pricing	10	10	0	0	0	10	0	30	0	10	20	0	0	20	10	0	120	7.50
PROTOTYPE MANUFACTURE	*10*	*10*	*0*	*0*	*0*	*20*	*60*	*50*	*0*	*20*	*60*	*10*	*0*	*10*	*20*	*50*	*320*	*4.00*
Component Procurement	0	0	0	0	0	10	20	0	0	0	10	10	-10	0	10	10	60	3.75
Card or Board Assembly	0	0	0	0	0	0	10	10	0	0	10	0	0	0	0	10	40	2.50
Module Assembly	0	0	0	0	0	0	10	20	0	0	10	0	0	0	0	10	50	3.13
Box or Chassis Assembly	0	0	0	0	0	0	10	20	0	10	10	0	0	0	0	10	60	3.75
Functional Test and Checkout	10	10	0	0	0	10	10	0	0	10	20	0	10	10	10	10	110	6.88
EQUIPMENT TEST	*20*	*100*	*0*	*0*	*0*	*80*	*180*	*80*	*0*	*50*	*70*	*20*	*-20*	*40*	*100*	*120*	*840*	*8.75*
Part/Component Accept. Test	0	20	0	0	0	0	30	10	0	10	10	0	0	0	10	10	100	6.25
Breadboard Tests	0	10	0	0	0	10	30	0	0	0	10	0	0	0	10	10	80	5.00
Brassboard Tests	0	20	0	0	0	10	30	0	0	0	20	0	0	0	10	10	100	6.25
Equip. Performance Demo.	0	20	0	0	0	10	30	10	0	0	10	0	0	20	10	30	140	8.75
Equipment Environmental Tests	0	20	0	0	0	20	30	30	0	10	0	10	-10	0	30	30	170	10.63
Equipment Reliability Tests	20	10	0	0	0	30	30	30	0	30	20	10	-10	20	30	30	250	15.63
QUALITY ASSURANCE	*10*	*110*	*0*	*0*	*0*	*40*	*80*	*50*	*0*	*0*	*40*	*10*	*0*	*40*	*20*	*70*	*470*	*7.34*
Quality Engineering	0	20	0	0	0	10	20	10	0	0	10	10	0	10	10	20	120	7.50
Inspection	0	30	0	0	0	10	20	10	0	0	10	0	0	10	10	10	110	6.88
In-Process Monitoring	0	30	0	0	0	10	20	10	0	0	10	0	0	0	0	20	100	6.25
Test Monitoring	10	30	0	0	0	10	20	20	0	0	10	0	0	20	0	20	140	8.75
PROGRAM MANAGEMENT	*30*	*20*	*10*	*10*	*0*	*20*	*0*	*0*	*0*	*0*	*20*	*0*	*10*	*20*	*10*	*20*	*170*	*10.63*
Cost Tracking	30	20	1C	10	0	20	0	0	0	0	20	0	10	20	10	20	170	10.63
FINANCIAL MANAGEMENT	*70*	*80*	*20*	*0*	*0*	*70*	*70*	*70*	*0*	*20*	*80*	*0*	*0*	*80*	*50*	*50*	*660*	*10.31*
Production Cost Analysis	20	20	0	0	0	10	20	30	0	0	20	0	10	30	10	20	190	11.88
Economic Escalation Analysis	0	20	0	0	0	30	10	30	0	0	20	0	0	10	10	0	130	8.13
Life-Cycle Cost Analysis	30	20	20	0	0	10	30	10	0	20	20	0	-10	30	20	20	220	13.75
Program Financial Control	20	20	0	0	0	20	10	0	0	0	20	0	0	10	10	10	120	7.50
PRODUCT SUPPORT	*100*	*60*	*0*	*30*	*30*	*40*	*40*	*70*	*0*	*70*	*80*	*0*	*-30*	*20*	*30*	*60*	*600*	*9.38*
Spares Requirements	30	20	0	0	0	10	0	0	0	20	20	0	-10	10	10	0	110	6.88
Container Design and Analysis	10	10	0	0	0	0	0	20	0	20	20	0	0	0	10	10	100	6.25
STE/AGE Design and Analysis	30	20	0	0	0	10	10	20	0	10	20	0	-20	0	0	20	120	7.50
Logistics Planning	30	10	0	30	30	20	30	30	0	20	20	0	0	10	10	30	270	16.88
PRODUCTION ENGINEERING	*0*	*50*	*0*	*0*	*0*	*20*	*0*	*50*	*0*	*0*	*40*	*0*	*0*	*20*	*20*	*20*	*220*	*6.88*
Producibility Analysis	0	30	0	0	0	10	0	20	0	0	20	0	0	10	10	10	110	6.88
Manufacturing Analysis	0	20	0	0	0	10	0	30	0	0	20	0	0	10	10	10	110	6.88
VALUE ENGINEERING	*0*	*10*	*0*	*0*	*0*	*10*	*30*	*10*	*0*	*0*	*30*	*0*	*0*	*0*	*10*	*0*	*100*	*6.25*
DATA AND REPORTS	*20*	*30*	*20*	*0*	*0*	*0*	*20*	*10*	*0*	*20*	*-10*	*0*	*-10*	*0*	*0*	*20*	*120*	*7.50*
CONTRACT MANAGEMENT	*20*	*20*	*10*	*0*	*0*	*10*	*20*	*10*	*0*	*10*	*20*	*0*	*0*	*20*	*0*	*10*	*150*	*9.38*
TOTAL	*510*	*1020*	*130*	*50*	*30*	*500*	*800*	*710*	*0*	*420*	*680*	*200*	*-40*	*470*	*560*	*780*	*6820*	
AVERAGE (PERCENT)**	*9.81*	*19.62*	*2.50*	*0.96*	*0.58*	*9.62*	*15.38*	*13.65*	*0*	*8 08*	*13.08*	*3.85*	*-0.77*	*9.04*	*10.77*	*15.00*		*8.20*

*Italicized numbers for each major heading are totals of subelements.

**The average impact is based on the average of all subelements. Because of rounding, the average of the major element totals is 8.17 percent.

Table 11. WARRANTY IMPACT IF WARRANTY WERE FIRM AND NOT AN OPTION

DEVELOPMENT PROGRAM ELEMENT	PERCENT CHANGE IN DEVELOPMENT PROGRAM EFFORT																	
	CONTRACTORS																Total	Average
	A	B	C	D	E	F	G	H	I	J*	K	L	M	N	O	P		
DESIGN**	*50*	*240*	*0*	*10*	*0*	*120*	*300*	*130*	*0*		*190*	*130*	*0*	*190*	*160*	*130*	*1650*	*11.00*
Circuit	0	20	0	0	0	10	30	20	0		20	20	0	20	0	10	150	10.00
Card and Board	0	30	0	0	0	20	30	20	0		20	10	0	20	10	10	170	11.33
Module	0	30	0	0	0	20	30	30	0		20	20	0	20	30	10	210	14.00
SRA	0	30	0	0	0	20	30	20	0		20	20	0	20	30	10	200	13.33
LRU or FLU	10	20	0	0	0	0	30	0	0		20	20	0	20	20	20	160	10.67
System Architecture	10	20	0	0	0	0	30	20	0		10	10	0	20	10	30	160	10.67
Built-in Test	20	30	0	10	0	0	30	0	0		20	10	0	20	20	30	190	12.67
Test Equipment	30	30	0	0	0	30	30	20	0		20	10	0	20	20	20	230	15.33
Ground Support Equipment	-20	10	0	0	0	20	20	0	0		20	10	0	20	20	-10	100	6.67
Production Tooling	0	20	0	0	0	0	30	0	0		20	0	0	10	0	0	80	5.33
ANALYSIS	*150*	*230*	*70*	*0*	*0*	*40*	*300*	*170*	*0*		*100*	*130*	*70*	*80*	*160*	*200*	*1700*	*11.33*
Thermal	20	30	0	0	0	0	30	30	0		10	30	0	0	10	30	190	12.67
Stress	0	20	0	0	0	0	30	30	0		10	10	0	0	10	20	130	8.67
EMC	0	20	0	0	0	0	30	0	0		10	10	0	0	0	10	80	5.33
Environment	10	20	0	0	0	0	30	30	0		10	10	0	10	30	30	180	12.00
Failure-Mode-Effects	30	20	0	0	0	10	30	0	0		10	10	20	20	30	20	200	13.33
Reliability	30	20	20	0	0	20	30	30	0		10	20	20	20	30	30	280	18.67
Maintainability	20	30	30	0	0	0	30	20	0		10	10	10	10	10	30	210	14.00
Producibility	0	30	0	0	0	0	30	20	0		10	0	20	20	10	0	140	9.33
Optimum Repair Level	20	20	20	0	0	10	30	0	0		10	10	0	0	20	20	160	10.67
Cost-Performance	20	20	0	0	0	0	30	10	0		10	20	0	0	10	10	130	8.67
MATERIALS AND PURCHASED PARTS	*30*	*60*	*0*	*0*	*0*	*30*	*90*	*60*	*0*		*60*	*60*	*30*	*50*	*30*	*30*	*530*	*11.78*
Part Selection	10	20	0	0	0	10	30	20	0		20	20	10	20	10	20	190	12.67
Vendor Screening	10	30	0	0	0	10	30	10	0		20	20	20	20	10	10	190	12.67
Cost Estimating and Pricing	10	10	0	0	0	10	30	30	0		20	20	0	10	10	0	150	10.00
PROTOTYPE MANUFACTURE	*10*	*10*	*0*	*0*	*0*	*20*	*150*	*50*	*0*		*50*	*30*	*60*	*10*	*60*	*50*	*500*	*6.67*
Component Procurement	0	0	0	0	0	10	30	0	0		10	20	10	0	20	10	110	7.33
Card or Board Assembly	0	0	0	0	0	0	30	10	0		10	0	10	0	10	10	80	5.33
Module Assembly	0	0	0	0	0	0	30	20	0		10	0	10	0	10	10	90	6.00
Box or Chassis Assembly	0	0	0	0	0	0	30	20	0		10	0	10	0	10	10	90	6.00
Functional Test and Checkout	10	10	0	0	0	10	30	0	0		10	10	20	10	10	10	130	8.67
EQUIPMENT TEST	*70*	*100*	*0*	*0*	*0*	*80*	*180*	*80*	*0*		*110*	*60*	*40*	*40*	*120*	*120*	*1000*	*11.11*
Part/Component Accept. Test	10	20	0	0	0	0	30	10	0		20	10	10	0	20	10	140	9.33
Breadboard Tests	10	10	0	0	0	10	30	0	0		20	0	0	0	10	10	100	6.67
Brassboard Tests	10	20	0	0	0	10	30	0	0		20	0	10	20	10	10	140	9.33
Equip. Performance Demo.	10	20	0	0	0	10	30	10	0		20	10	0	0	20	30	160	10.67
Equipment Environmental Tests	10	20	0	0	0	20	30	30	0		10	20	0	0	30	30	200	13.33
Equipment Reliability Tests	20	10	0	0	0	30	30	30	0		20	20	20	20	30	30	260	17.33
QUALITY ASSURANCE	*40*	*110*	*0*	*0*	*0*	*40*	*120*	*50*	*0*		*40*	*30*	*60*	*30*	*30*	*70*	*620*	*10.33*
Quality Engineering	10	20	0	0	0	10	30	10	0		10	10	20	10	10	20	160	10.67
Inspection	10	30	0	0	0	10	30	10	0		10	0	10	10	20	10	150	10.00
In-Process Monitoring	10	30	0	0	0	10	30	10	0		10	10	10	10	0	20	150	10.00
Test Monitoring	10	30	0	0	0	10	30	20	0		10	10	20	0	0	20	160	10.67
PROGRAM MANAGEMENT	*30*	*20*	*10*	*10*	*0*	*20*	*30*	*0*	*0*		*20*	*10*	*0*	*20*	*20*	*20*	*210*	*14.00*
Cost Tracking	30	20	10	10	0	20	30	0	0		20	10	0	20	20	20	210	14.00
FINANCIAL MANAGEMENT	*50*	*80*	*50*	*0*	*0*	*70*	*120*	*70*	*0*		*70*	*0*	*10*	*40*	*50*	*50*	*660*	*11.00*
Production Cost Analysis	20	20	0	0	0	10	30	30	0		20	0	0	10	10	20	170	11.33
Economic Escalation Analysis	0	20	30	0	0	30	30	30	0		10	0	0	10	10	0	170	11.33
Life-Cycle Cost Analysis	10	20	20	0	0	10	30	10	0		20	0	10	10	20	20	180	12.00
Program Financial Control	20	20	0	0	0	20	30	0	0		20	0	0	10	10	10	140	9.33
PRODUCT SUPPORT	*70*	*60*	*0*	*30*	*30*	*40*	*120*	*70*	*0*		*80*	*-20*	*30*	*40*	*30*	*60*	*640*	*10.67*
Spares Requirements	20	20	0	0	0	10	30	0	0		20	-10	10	10	10	0	120	8.00
Container Design and Analysis	10	10	0	0	0	0	30	20	0		20	0	0	10	10	10	120	8.00
STE/AGE Design and Analysis	20	20	0	0	0	10	30	20	0		20	0	20	10	0	20	170	11.33
Logistics Planning	20	10	0	30	30	20	30	30	0		20	-10	0	10	10	30	230	15.33
PRODUCTION ENGINEERING	*0*	*50*	*0*	*0*	*0*	*20*	*60*	*50*	*0*		*20*	*0*	*30*	*40*	*20*	*20*	*310*	*10.33*
Producibility Analysis	0	30	0	0	0	10	30	20	0		10	0	20	20	10	10	160	10.66
Manufacturing Analysis	0	20	0	0	0	10	30	30	0		10	0	10	20	10	10	150	10.00
VALUE ENGINEERING	*0*	*10*	*0*	*0*	*0*	*10*	*30*	*10*	*0*		*10*	*0*	*0*	*0*	*10*	*0*	*80*	*5.33*
DATA AND REPORTS	*10*	*30*	*20*	*0*	*0*	*0*	*30*	*10*	*0*		*20*	*20*	*20*	*0*	*0*	*20*	*180*	*12.00*
CONTRACT MANAGEMENT	*10*	*20*	*0*	*0*	*0*	*10*	*30*	*10*	*0*		*20*	*10*	*0*	*20*	*0*	*10*	*140*	*9.33*
TOTAL	*520*	*1020*	*150*	*50*	*30*	*500*	*1560*	*760*	*0*		*790*	*460*	*350*	*560*	*690*	*780*	*8220*	
AVERAGE (PERCENT)***	*10.00*	*19.62*	*2.88*	*0.96*	*0.58*	*9.62*	*30.00*	*14.62*	*0*		*15.19*	*8.85*	*6.73*	*10.77*	*13.27*	*15.00*		*10.54*

*Contractor J did not respond to this condition because he felt it was not applicable to his development program. Therefore the averages presented are based on 15 contractors.

**Italicized numbers for each major heading are totals of subelements.

***The average impact is based on the average of all subelements. Because of rounding, the average of the major element totals is 10.38 percent.

Table 12. LEVERAGE VALUES FOR POTENTIAL IMPACTS

Beginning/Actual		Firm/Beginning		Firm/Actual	
Ratio	Program Element	Ratio	Program Element	Ratio	Program Element
2.50	Value Engineering	1.67	Prototype Manufacturing	3.13	Prototype Manufacturing
1.88	Prototype Manufacturing	1.60	Data and Reports	2.54	Production Engineering
1.69	Production Engineering	1.50	Production Engineering	2.20	Design
1.65	Equipment Test	1.41	Quality Assurance	2.13	Quality Assurance
1.59	Design	1.39	Design	2.13	Value Engineering
1.53	Financial Management	1.38	Materials/Purchased Parts	2.09	Equipment Test
1.52	Quality Assurance	1.32	Program Management	1.88	Materials/Purchased Parts
1.46	Product Support	1.27	Equipment Test	1.87	Program Management
1.42	Program Management	1.22	Analysis	1.74	Data and Reports
1.37	Materials/Purchased Parts	1.14	Product Support	1.66	Product Support
1.34	Analysis	1.07	Financial Management	1.64	Financial Management
1.25	Contract Management	.99	Contract Management	1.63	Analysis
1.09	Data and Reports	.85	Value Engineering	1.24	Contract Management
1.50	AVERAGE*	1.29	AVERAGE*	1.92	AVERAGE*

*Weighted according to the number of subelements contained in each program element category.

Table 12 provides a ranking of the above multiplier ratios for each of the major development program categories. The following sections discuss the individual development program categories and their constituent subelements.

2. Design

Figure 7 presents a histogram illustrating the impact of warranties on the design program elements under the three conditions--*actual, beginning,* and *firm.*

Table 13 presents the leverage ratios under the three conditions for the total design group and for those elements on which a high degree of leverage is obtained.

Table 13. IMPACT LEVERAGE UPON DESIGN

Design Category	Beginning/ Actual	Firm/ Beginning	Firm/ Actual
Average	*1.59*	*1.39*	*2.20*
Module	2.00	1.40	2.80
SRA	1.88	1.42	2.67
Circuit	1.57	1.45	2.28
System Architecture	1.67	1.14	1.90
Test Equipment	1.31	1.44	1.89

The areas of greatest design impact reported by the contractors under the *beginning* and *firm* conditions are largely an extension of those cited in the actual development programs--namely, BITE, system architecture, sensors-indicators-protective circuits, and higher inherent design reliability. Many examples

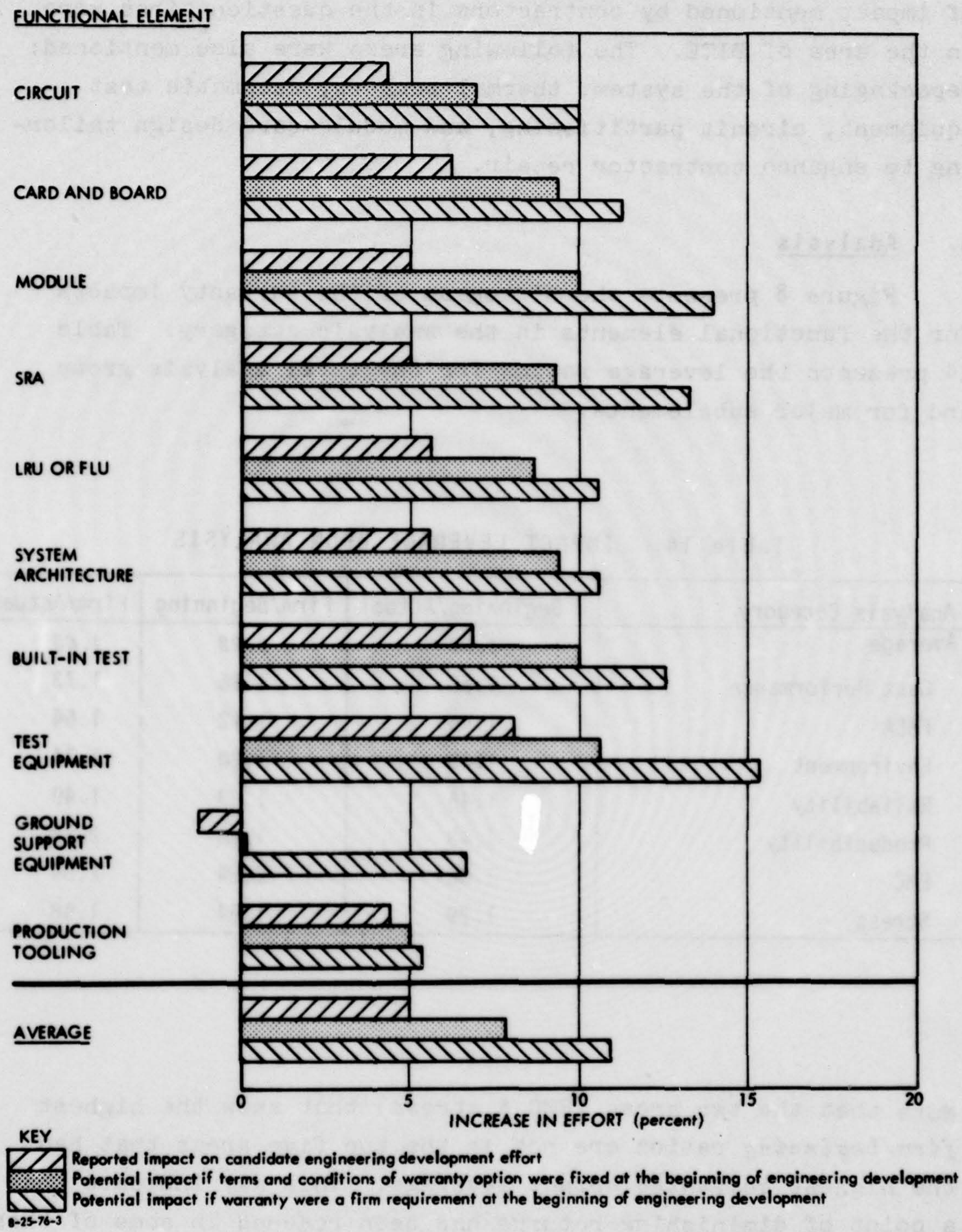

Figure 7. SUMMARY OF WARRANTY IMPACTS: DESIGN

of impact mentioned by contractors in the questionnaires were in the area of BITE. The following areas were also mentioned: repackaging of the system, thermal sensors, automatic test equipment, circuit partitioning, and module-card design tailoring to enhance contractor repair.

3. Analysis

Figure 8 presents the histogram of the warranty impacts for the functional elements in the analysis category. Table 14 presents the leverage ratios for the total analysis group and for major subelements.

Table 14. IMPACT LEVERAGE UPON ANALYSIS

Analysis Category	Beginning/Actual	Firm/Beginning	Firm/Actual
Average	*1.34*	*1.22*	*1.63*
Cost Performance	1.50	1.16	1.73
FMEA	1.46	1.12	1.64
Environment	1.45	1.20	1.74
Reliability	1.45	1.03	1.49
Producibility	1.43	1.49	2.13
EMC	1.00	2.84	2.84
Stress	1.29	1.54	1.98

Note that the two areas (EMC & stress) that show the highest *firm/beginning* ratios are not in the top five areas that had the highest *beginning/actual* leverage. This may indicate that a point of diminishing returns has been reached in some of these areas. Cost-performance analysis showed the highest leverage of

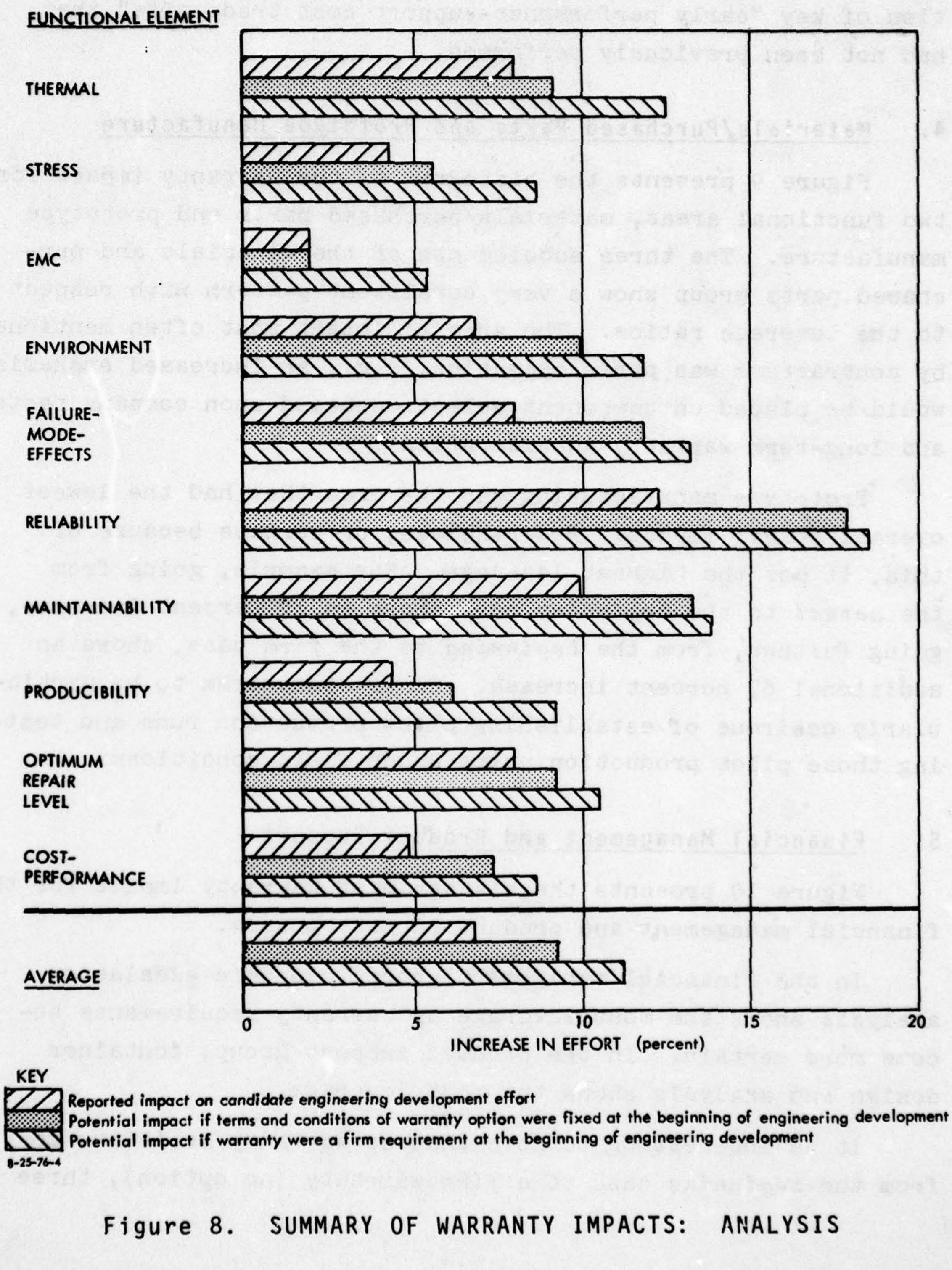

Figure 8. SUMMARY OF WARRANTY IMPACTS: ANALYSIS

the *beginning/actual* comparison, which indicates the consideration of key "early performance-support cost trade-offs" that had not been previously performed.

4. Materials/Purchased Parts and Prototype Manufacture

Figure 9 presents the histogram of the warranty impact for two functional areas, materials/purchased parts and prototype manufacture. The three subelements of the materials and purchased parts group show a very consistent pattern with respect to the leverage ratios. The area of impact most often mentioned by contractors was parts selection, e.g., an increased emphasis would be placed on component selection based upon company tests and long-term warranty considerations.

Prototype manufacturing was the area that had the lowest overall *actual* impact. Nevertheless, or perhaps because of this, it has the highest leverage. For example, going from the *actual* to the *beginning* case shows an 88 percent increase, going further, from the *beginning* to the *firm* case, shows an additional 67 percent increase. Contractors seem to be particularly desirous of establishing pilot production runs and testing those pilot production units under field conditions.

5. Financial Management and Product Support

Figure 10 presents the histogram of warranty impact for the financial management and product support groups.

In the financial management group, economic escalation analysis shows the most leverage as warranty requirements become more certain. In the product support group, container design and analysis shows the most leverage.

It is interesting to note that as warranty decisions go from the *beginning* case to a *firm* warranty (no option), three

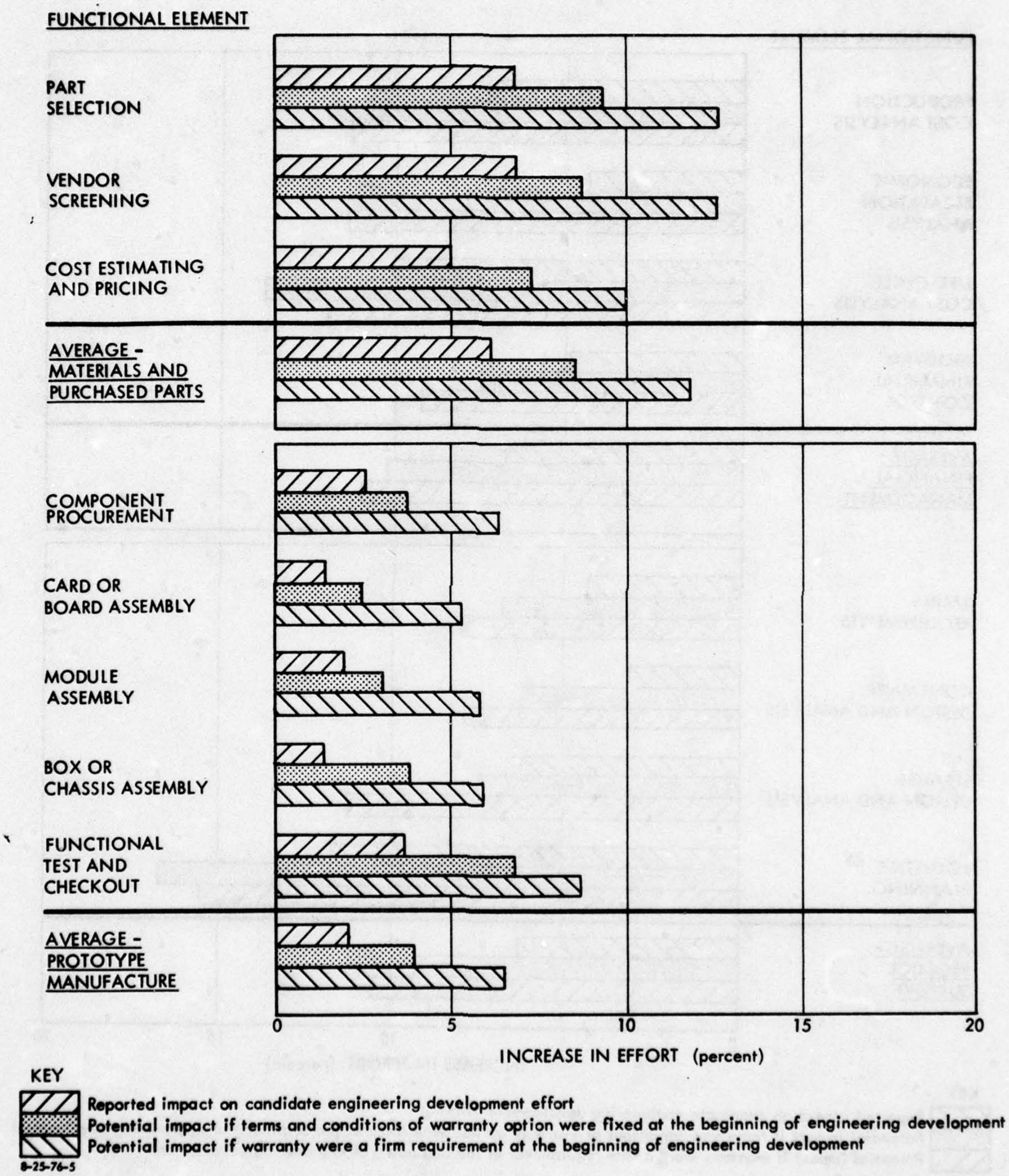

Figure 9. SUMMARY OF WARRANTY IMPACTS: MATERIALS/PURCHASED PARTS AND PROTOTYPE MANUFACTURE

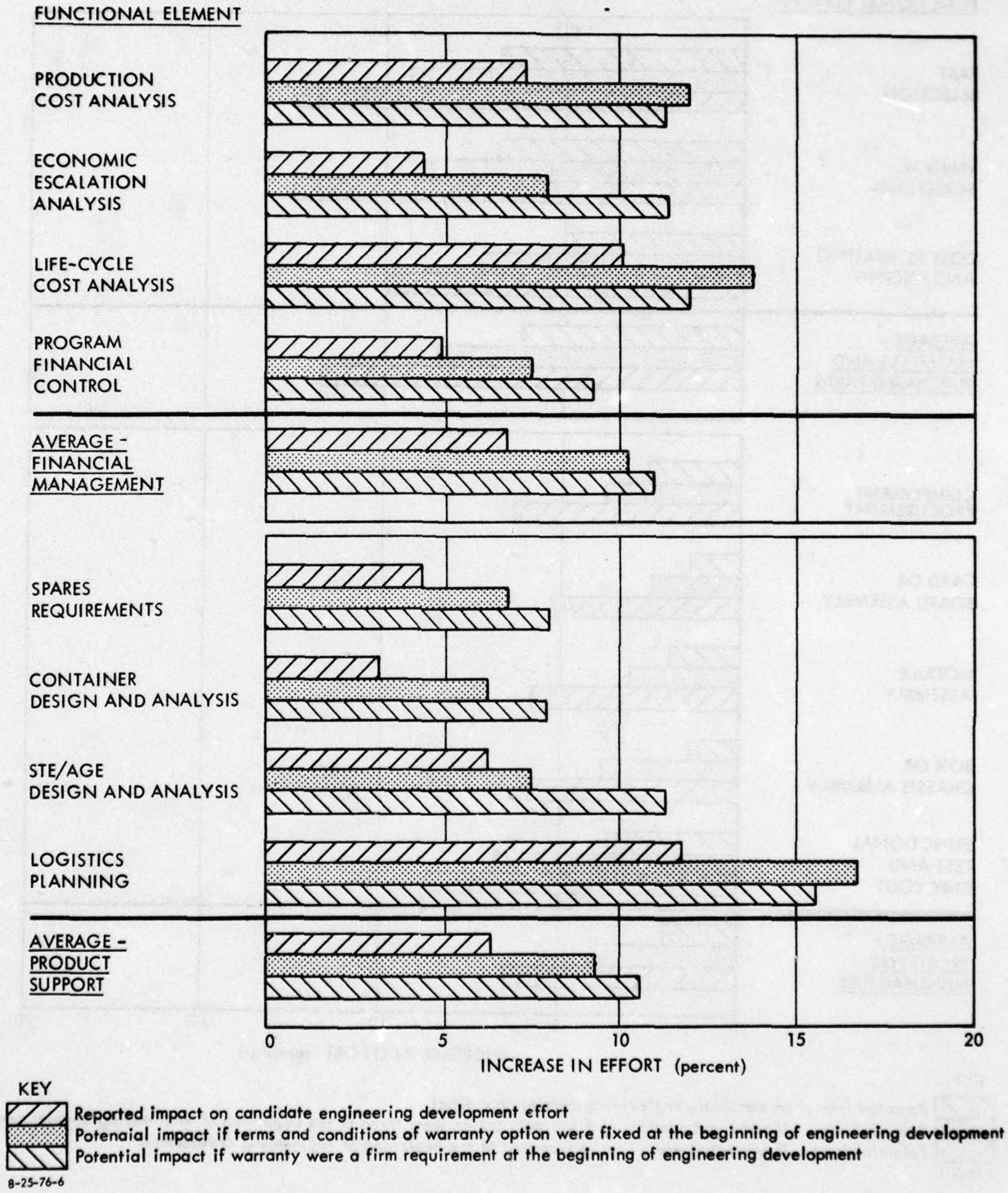

Figure 10. SUMMARY OF WARRANTY IMPACTS: FINANCIAL MANAGEMENT AND PRODUCT SUPPORT

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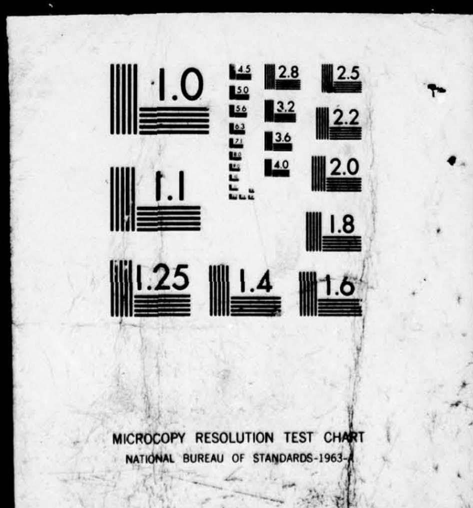

elements decrease in effort--production-cost analysis, life-cycle cost analysis, and logistics planning. This is not unexpected, since there are fewer alternatives to consider if the warranty is firm.

6. Equipment Test and Quality Assurance

Figure 11 presents the warranty impacts in the equipment test and quality assurance categories under the three conditions.

The impact on equipment reliability demonstration and verification tests goes up markedly in moving from the *actual* to the *beginning* cases but less dramatically for the *firm* case. It may be that increased reliability testing has progressed almost as far as possible in the *beginning* case and there is little left to do in the *firm* case, because the contractors typically do not have the freedom to design the tests the way they would like.[1] Also, the tests may have been expanded as much as possible to accord with the factory maintenance philosophy while still staying within required test specifications.

7. Miscellaneous Areas

To complete the list of development program elements, Figure 12 presents the histogram of warranty impacts for the following areas:

- Program management (cost tracking)
- Production engineering
- Producibility analysis
- Manufacturing analysis
- Value engineering
- Data and reports
- Contract management.

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[1]Or perhaps the development program funding and schedule barriers still are constraints.

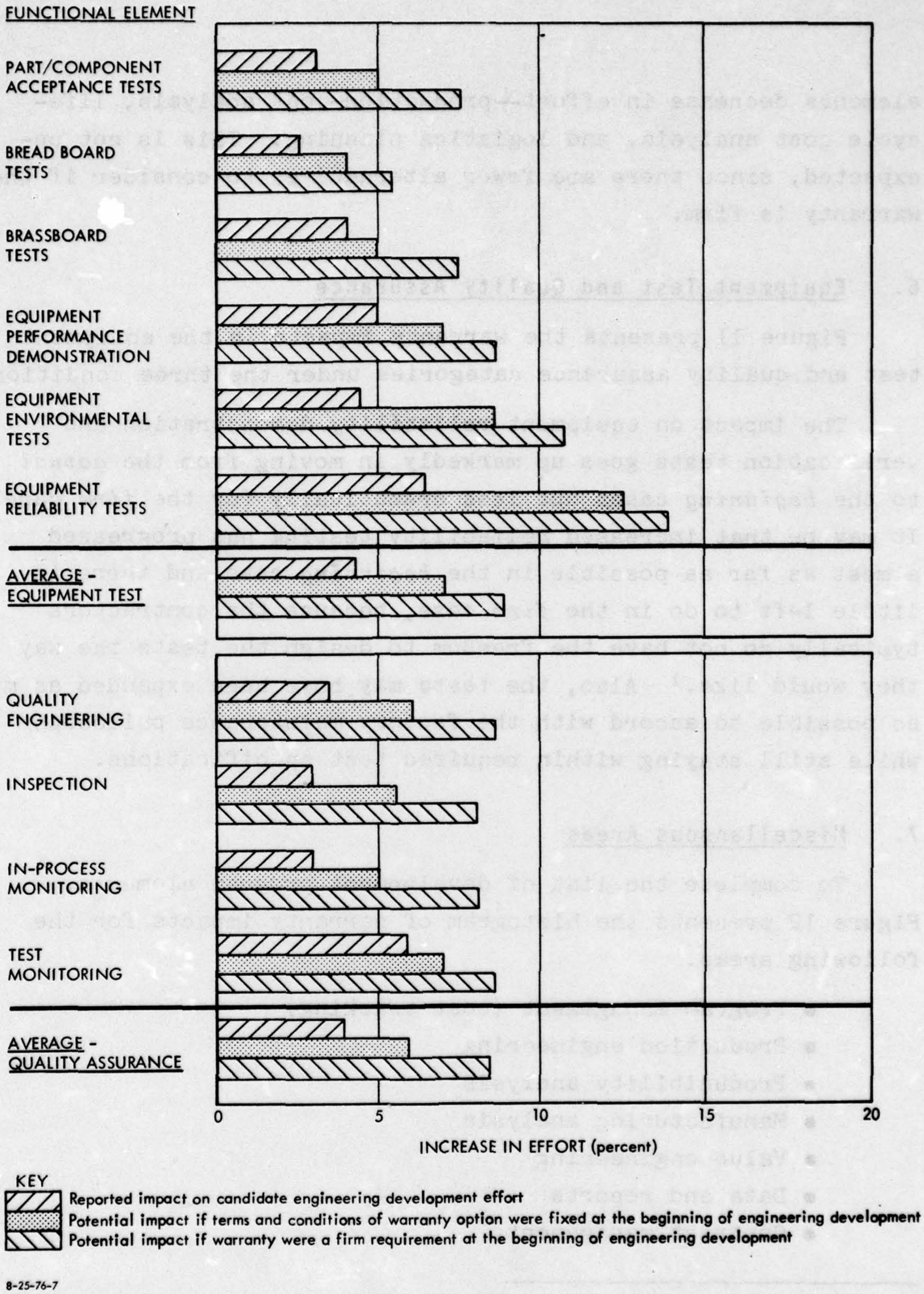

Figure 11. SUMMARY OF WARRANTY IMPACTS: EQUIPMENT TEST AND QUALITY ASSURANCE

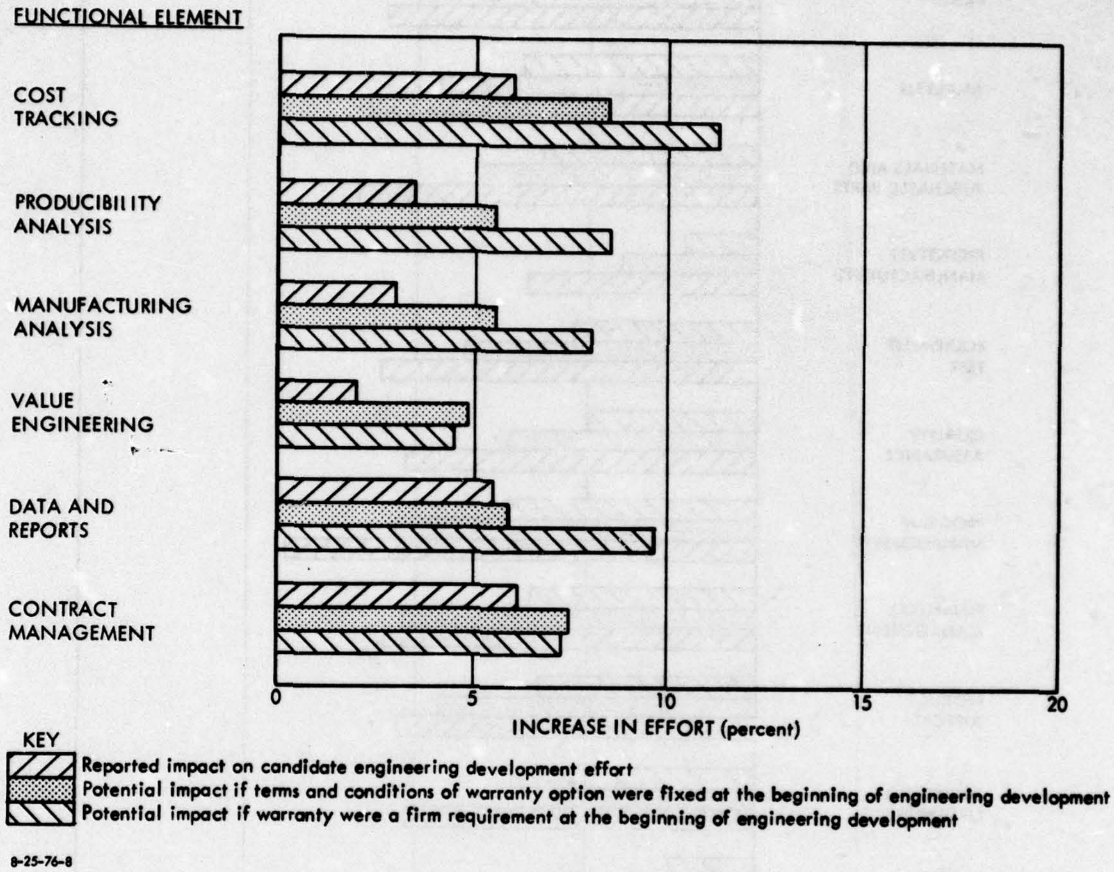

Figure 12. SUMMARY OF WARRANTY IMPACTS: MISCELLANEOUS

Cost tracking becomes increasingly more important as the conditions are relaxed. It had the eleventh highest impact in the *actual* case, the seventh highest in the *beginning* case, and the fifth highest in the *firm* case.

8. Combined Development Program Impacts

Figure 13 summarizes the reported warranty impacts under the three conditions for the thirteen major functional element categories. From the figure, it can be seen that the greatest

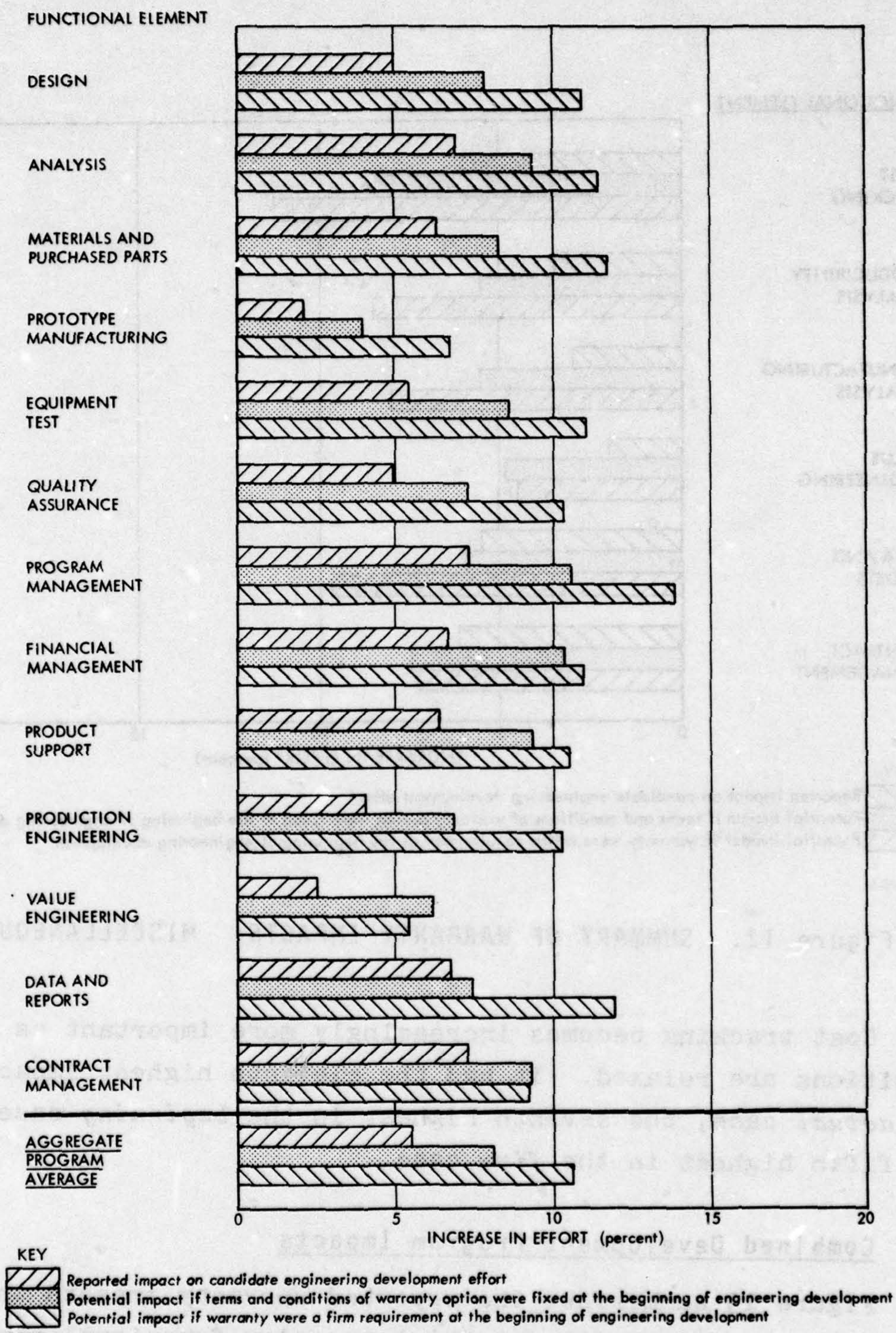

Figure 13. SUMMARY OF WARRANTY IMPACTS ON CANDIDATE ELECTRONICS DEVELOPMENT PROGRAMS

overall average impact for the *firm* conditions is registered in program management (14 percent), followed by data and reports (12 percent) and materials and purchased parts (11.75 percent). If only the *beginning* conditions prevail, the greatest impact is reported again in the program management area (10.6 percent), followed by financial management (10.3 percent) and contract management (9.4 percent). Note that the last two are indirect cost elements.

As observed in Chapter IV, not all contractors reported impacts for each of the program elements as the barriers were removed. If only those program elements that received an impact are considered, the aggregate average impact is correspondingly higher in each category, with data and reports, program management, production engineering, and materials management leading the impact estimates when the warranty is *firm.* A summary of the reported impacts for both the aggregate sample and the subset of program elements receiving an impact is presented in Table 15.[1] As shown by the table, those contractors who reported impacts (other than zero), on the average, did not discriminate between the *actual* case and the case in which warranty requirements are known at the *beginning* of engineering development.

One reason for the small differences in sample reported impacts is that, for five programs, there was no difference[2] in most of the impacts due to the imposed conditions. For two contractors, the systems were significantly developed and tested prior to receipt of the RFPs. The other contractors either treated the option as a "firm requirement" and proceeded on the basis that the option would be exercised or indicated that, "a

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[1]The authors recognize that this analysis raises two difficult research questions. First, should a reported impact of zero in a program element be counted? Second, what interpretation should be made for the subset consisting of only the program elements receiving an impact other than zero?

[2]All questionnaire entries for each of the 52 development program elements were identical for the *actual, beginning,* and *firm* cases.

Table 15. COMPARISON OF WARRANTY IMPACTS: ACTUAL, BEGINNING, FIRM

Program Category	Percent Impact for Total Contractor Sample			Percent Impact for Only Those Program Elements Receiving Impacts (other than zero)			Number of Contractors Reporting Impacts (other than zero)		
	Actual	Begin.	Firm	Actual	Begin.	Firm	Actual	Begin.	Firm
Design	5.00	7.94	11.00	8.89	9.77	15.00	9	13	11
Analysis	6.94	9.31	11.33	11.10	12.41	14.17	10	12	12
Materials/Pur. Parts	6.25	8.54	11.75	12.50	11.39	16.06	8	12	11
Prototype Manufacture	2.13	4.00	6.67	4.25	5.82	9.09	8	11	11
Equipment Test	5.37	8.75	11.11	10.63	11.67	15.15	8	12	11
Quality Assurance	4.84	7.34	10.33	9.69	11.75	14.09	8	10	11
Program Management	7.50	10.63	14.00	17.14	17.00	19.09	7	10	11
Financial Management	6.72	10.31	11.00	13.44	15.00	15.00	8	11	11
Product Support	6.41	9.38	10.67	11.39	11.54	12.31	9	13	13
Production Engineering	4.06	6.88	10.33	13.00	15.71	17.22	5	7	9
Value Engineering	2.50	6.25	5.33	13.33	16.67	13.33	3	6	6
Data and Reports	6.88	7.50	12.00	18.33	13.33	20.00	6	9	9
Contract Management	7.50	9.38	9.33	17.14	15.00	15.56	7	10	9
AVERAGE	5.54	8.17	10.38	12.37	12.85	15.08	7.4	10.5	10.4

Note: Actual = reported impact on candidate engineering development program.
Beginning = potential impact if terms and conditions of warranty option were fixed at beginning of engineering development.
Firm = potential impact if warranty were firm requirement at the beginning of engineering development.

responsible contractor cannot distinguish any difference between impact of a priced option and a firm obligation since a warranty commitment cannot be economically fulfilled unless considered during initial design."

In two additional programs, the change in impact due to the imposed conditions was small--in both cases the *actual* impact was equal to the *beginning*, and the *firm* case registered a small increase over both.

In the remaining nine programs, substantial effects were observed as a result of varying the conditions. In three development programs, for example, the *actual* impact was zero, but it was estimated that there would have been an 8.1 percent, 9.6 percent, and 10.8 percent increase in effort, respectively, if the warranty terms and conditions had been known at the *beginning* of engineering development.

It should be noted that the *actual* situation in the six F-16 development programs was that the RIW terms and conditions *were known* at the *beginning* of engineering development.[1] The increase in the total impact *if* terms and conditions had not been negotiated at the beginning of engineering development for the F-16 programs is likely to have been greater than reported.

Examining the ten remaining contractor development programs not associated with the F-16 program, the increase in impact (going from *actual* to *beginning*) approaches 112 percent. This can be compared with the 50 percent increase in impact observable over all sixteen programs, as reflected on the histograms.

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[1]These were the F-16 avionics development programs, which were negotiated under subcontract purchase orders with General Dynamics. A key question for further analysis is whether these programs were really at the start of engineering development or whether they, in fact, were essentially at the end.

B. WARRANTY IMPACTS UNDER SPECIFICATION RELIEF

1. The Relationship Between Specification Relief and Warranty Impact

Increased specification relief was reported to be a potential condition under which the impact of warranties upon the design and development process would be increased. The situation to be considered is one in which *all* specifications and requirements are flexible and negotiable *except* for critical performance, cost, and reliability requirements.

The possibility of granting specification relief stems from the perceived responsibility of the contractor, under a warranty, to maintain his equipment over an extended period of time. Specification relief would allow contractors to transfer their efforts from meeting certain specifications to more productive areas by allowing them freedom to design, test, produce, and maintain equipment in a manner consonant with contractor maintenance.

The elimination of unnecessarily restrictive specifications has been advocated by many observers. The Electronics-X study, for example reported, "though these reference specifications are frequently related only remotely and indirectly to the objective of realizing the desired performance of the electronic system to which they apply, they provide a ready basis for rejection by Government inspectors of equipment that is totally satisfactory from a functional standpoint." Electronics-X also noted the successful approach of the commercial air transport industry, from which the warranty concept came, which allows much more freedom to manufacturers. One factor cited as leading to the success of this approach was summarized this way: "the widespread provision of long-term warranties by equipment suppliers assures the purchaser that he will get the

required functional performance despite his not specifying internal design details."[1]

The effects of increased specification relief are believed to be twofold--first, contractors can be innovative in their designs and program planning; and second, contractors can transfer time, money, and manpower required as part of the obligations associated with military specifications to areas of effort more compatible with warranty features.

Some military specifications affect the impact of warranties more than others. These would include, for example, reliability and maintainability demonstration test requirements. If these specifications were altered or waived, the contractors could afford to design and implement a series of reliability tests geared more to field reliability predictions. The argument for specification relief has been made frequently, but without a warranty the government heretofore has not had any assurance of product quality under specification relief.[2]

2. Contractor Responses

The subsystem contractors were asked to estimate the impact on the fifty-two program elements listed in the questionnaire under the condition that the warranty requirement was firm *and in addition* all specifications and requirements were flexible and negotiable except for critical performance, cost, and reliability requirements. The questionnaire results are displayed in Table 16. The responses were then compared, as before, with the impacts estimated for the *firm* and *actual* cases, as shown in Table 17. Table 17 reveals that a general reduction

[1]Howard P. Gates, Jr., et al., *Electronics-X: A Study of Military Electronics with Particular Reference to Cost and Reliability*, in 2 vols., IDA Report R-195 (1974), II: 290.

[2]Except for the standard correction-of-deficiencies contract clause.

Table 16. POTENTIAL WARRANTY IMPACT UNDER SPECIFICATION RELIEF

DEVELOPMENT PROGRAM ELEMENT	PERCENT CHANGE IN DEVELOPMENT PROGRAM EFFORT																	
	CONTRACTORS																	
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P*	Total	Average
DESIGN**	*0*	*240*	*0*	*10*	*0*	*-30*	*0*	*140*	*60*	*90*	*90*	*0*	*-40*	*190*	*110*		*850*	*5.67*
Circuit	-10	20	0	0	0	-20	0	20	10	0	10	0	0	20	0		50	3.33
Card and Board	-10	30	0	0	0	-10	0	20	10	0	10	0	0	20	0		70	4.67
Module	-10	30	0	0	0	-10	0	30	10	0	10	0	0	20	20		100	6.67
SRA	-10	30	0	0	0	-10	0	20	10	0	10	0	0	20	20		90	6.00
LRU or FLU	0	20	0	0	0	0	0	0	20	20	10	0	0	20	10		100	6.67
System Architecture	10	20	0	0	0	0	0	30	0	20	0	0	0	20	10		110	7.33
Built-in Test	20	30	0	10	0	-10	0	0	-10	20	10	0	0	20	20		110	7.33
Test Equipment	30	30	0	0	0	20	0	20	0	0	10	0	-20	20	20		130	8.67
Ground Support Equipment	-20	10	0	0	0	10	0	0	0	10	10	0	-20	20	10		30	2.00
Production Tooling	0	20	0	0	0	0	0	0	0	20	10	0	0	10	0		60	4.00
ANALYSIS	*100*	*230*	*100*	*0*	*0*	*-30*	*0*	*190*	*100*	*110*	*90*	*0*	*-10*	*80*	*60*		*1120*	*7.47*
Thermal	10	30	0	0	0	0	0	30	20	10	0	0	0	0	10		110	7.33
Stress	0	20	0	0	0	0	0	30	20	10	0	0	0	0	10		90	6.00
EMC	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0		20	1.33
Environment	10	20	0	0	0	0	0	30	20	0	0	0	0	10	30		120	8.00
Failure-Mode-Effects	10	20	0	0	0	0	0	0	10	20	10	0	0	20	30		120	8.00
Reliability	20	20	30	0	0	-10	0	30	10	30	20	0	0	20	30		200	13.33
Maintainability	10	30	30	0	0	-10	0	30	10	20	20	0	0	10	10		160	10.67
Producibility	0	30	0	0	0	0	0	30	0	0	10	0	0	20	10		100	6.67
Optimum Repair Level	20	20	20	0	0	-10	0	-20	0	0	20	0	-10	0	20		60	4.00
Cost-Performance	20	20	20	0	0	0	0	30	10	20	10	0	0	0	10		140	9.33
MATERIALS AND PURCHASED PARTS	*30*	*60*	*0*	*0*	*0*	*-30*	*0*	*60*	*20*	*30*	*30*	*0*	*-20*	*30*	*30*		*240*	*5.33*
Part Selection	10	20	0	0	0	-20	0	20	10	10	10	0	-10	10	10		70	4.67
Vendor Screening	10	30	0	0	0	-10	0	10	10	10	10	0	-10	10	10		80	5.33
Cost Estimating and Pricing	10	10	0	0	0	0	0	30	0	10	10	0	0	10	10		90	6.00
PROTOTYPE MANUFACTURE	*-50*	*10*	*0*	*0*	*0*	*0*	*0*	*50*	*20*	*20*	*0*	*0*	*-20*	*10*	*20*		*60*	*0.80*
Component Procurement	-10	0	0	0	0	0	0	0	0	0	0	0	0	0	10		0	0.00
Card or Board Assembly	-10	0	0	0	0	0	0	10	0	0	0	0	-10	0	0		-10	-0.66
Module Assembly	-10	0	0	0	0	0	0	20	0	0	0	0	-10	0	0		0	0.00
Box or Chassis Assembly	-10	0	0	0	0	0	0	20	0	10	0	0	-10	0	0		10	0.66
Functional Test and Checkout	-10	10	0	0	0	0	0	0	20	10	0	0	10	10	10		60	4.00
EQUIPMENT TEST	*0*	*100*	*0*	*0*	*0*	*20*	*0*	*80*	*30*	*50*	*50*	*0*	*-30*	*-10*	*100*		*390*	*4.33*
Part/Component Accept. Test	0	20	0	0	0	10	0	10	10	10	10	0	-10	0	10		70	4.67
Breadboard Tests	0	10	0	0	0	-10	0	0	0	0	10	0	0	0	10		20	1.33
Brassboard Tests	0	20	0	0	0	-10	0	0	10	0	10	0	-10	0	10		30	2.00
Equip. Performance Demo.	0	20	0	0	0	0	0	10	0	0	10	0	0	10	10		60	4.00
Equipment Environmental Tests	0	20	0	0	0	10	0	30	0	10	0	0	0	-10	30		90	6.00
Equipment Reliability Tests	0	10	0	0	0	20	0	30	10	30	10	0	-10	-10	30		120	8.00
QUALITY ASSURANCE	*40*	*110*	*0*	*0*	*0*	*-40*	*0*	*10*	*0*	*0*	*0*	*0*	*0*	*30*	*20*		*170*	*2.83*
Quality Engineering	10	20	0	0	0	-10	0	0	0	0	0	0	0	10	10		40	2.67
Inspection	10	30	0	0	0	-10	0	0	0	0	0	0	0	10	10		50	3.33
In-Process Monitoring	10	30	0	0	0	-10	0	0	0	0	0	0	0	10	10		40	2.67
Test Monitoring	10	30	0	0	0	-10	0	10	0	0	0	0	0	0	0		40	2.67
PROGRAM MANAGEMENT	*30*	*20*	*10*	*10*	*0*	*10*	*0*	*0*	*0*	*0*	*10*	*0*	*0*	*0*	*10*		*100*	*6.67*
Cost Tracking	30	20	10	10	0	10	0	0	0	0	10	0	0	0	10		100	6.67
FINANCIAL MANAGEMENT	*50*	*80*	*50*	*0*	*0*	*70*	*0*	*80*	*0*	*20*	*40*	*0*	*-10*	*40*	*50*		*470*	*7.83*
Production Cost Analysis	20	20	0	0	0	10	0	30	0	0	10	0	0	10	10		110	7.33
Economic Escalation Analysis	0	20	30	0	0	30	0	30	0	0	10	0	0	10	10		140	9.33
Life-Cycle Cost Analysis	10	20	20	0	0	10	0	20	0	20	10	0	-10	10	20		130	8.67
Program Financial Control	20	20	0	0	0	20	0	0	0	0	10	0	0	10	10		90	6.00
PRODUCT SUPPORT	*-30*	*60*	*0*	*30*	*30*	*40*	*0*	*70*	*0*	*70*	*80*	*0*	*-10*	*40*	*30*		*410*	*6.83*
Spares Requirements	-10	20	0	0	0	10	0	0	0	20	20	0	0	10	10		80	5.33
Container Design and Analysis	10	10	0	0	0	0	0	20	0	20	20	0	0	10	10		100	6.67
STE/AGE Design and Analysis	-10	20	0	0	0	10	0	20	0	10	20	0	-10	10	0		70	4.67
Logistics Planning	-20	10	0	30	30	20	0	30	0	20	20	0	0	10	10		160	10.67
PRODUCTION ENGINEERING	*-20*	*50*	*0*	*0*	*0*	*20*	*0*	*60*	*0*	*0*	*40*	*0*	*0*	*40*	*20*		*210*	*7.00*
Producibility Analysis	-10	30	0	0	0	10	0	30	0	0	20	0	0	20	10		110	7.33
Manufacturing Analysis	-10	20	0	0	0	10	0	30	0	0	20	0	0	20	10		100	6.67
VALUE ENGINEERING	*0*	*10*	*0*	*0*	*0*	*10*	*0*	*30*	*0*	*0*	*20*	*0*	*0*	*0*	*10*		*80*	*5.33*
DATA AND REPORTS	*-20*	*30*	*20*	*0*	*0*	*0*	*0*	*-10*	*0*	*20*	*10*	*0*	*-10*	*0*	*0*		*40*	*2.67*
CONTRACT MANAGEMENT	*10*	*20*	*10*	*0*	*0*	*10*	*0*	*20*	*0*	*10*	*20*	*0*	*0*	*20*	*0*		*120*	*8.00*
TOTAL	*140*	*1020*	*190*	*50*	*30*	*60*	*0*	*780*	*220*	*420*	*480*	*0*	*-150*	*470*	*560*		*4260*	
AVERAGE (PERCENT)***	*2.69*	*19.62*	*3.65*	*0.96*	*0.58*	*0.96*	*0*	*15.00*	*4.23*	*8.08*	*9.23*	*0*	*-2.88*	*9.04*	*10.77*			*5.46*

*Contractor P did not respond to this condition; therefore averages are based on 15 contractors.

**Italicized numbers for each major heading are totals of subelements.

***The average impact is based on the average of all subelements. Because of rounding, the average of the major element totals is 5.59 percent.

Table 17. COMPARISON OF WARRANTY IMPACTS: ACTUAL, FIRM, SPECIFICATION RELIEF

Program Category	Percent Impact for Total Contractor Sample			Percent Impact for Only Those Program Elements Receiving Impacts (other than zero)			Number of Contractors Reporting Impacts (other than zero)		
	Actual	Firm	Spec. Relief	Actual	Firm	Spec. Relief	Actual	Firm	Spec. Relief
Design	5.00	11.00	5.67	8.89	15.00	8.50	9	11	10
Analysis	6.94	11.33	9.33	11.10	14.17	10.18	10	12	11
Materials/Pur. Parts	6.25	11.75	5.33	12.50	16.06	8.00	8	11	10
Prototype Manufacture	2.13	6.67	0.80	4.25	9.09	1.71	8	11	7
Equipment Test	5.37	11.11	4.33	10.63	15.15	7.22	8	11	9
Quality Assurance	4.84	10.33	2.83	9.69	14.09	7.08	8	11	6
Program Management	7.50	14.00	6.67	17.14	19.09	14.29	7	11	7
Financial Management	6.72	11.00	7.83	13.44	15.00	11.75	8	11	10
Product Support	6.41	10.67	6.83	11.39	12.31	9.32	9	13	11
Production Engineering	4.06	10.33	7.00	13.00	17.22	15.00	5	9	7
Value Engineering	2.50	5.33	5.33	13.33	13.33	16.00	3	6	5
Data and Reports	6.88	12.00	2.67	18.33	20.00	5.71	6	9	7
Contract Management	7.50	9.33	8.00	17.14	15.56	15.00	7	9	8
AVERAGE	5.54	10.38	5.59	12.37	15.08	9.94	7.4	10.4	8.3
Percent Change from Actual	---	+87.4	+1.0	---	+21.9	-19.6			

in effort beyond that reported for the *firm* case would be the result under conditions of specification relief. Table 18 summarizes the reduction of effort for each of the development program groups from the total contractor sample.

A survey of the sixteen contractor development programs reveals that four showed *no change* due to specification relief, three showed an increase in effort due to specification relief, and the remaining seven showed reductions in effort ranging up to 30 percent.

Table 18. REDUCTION IN EFFORT DUE TO SPECIFICATION RELIEF

	Percent Reduction
Data and Reports	9.33
Quality Assurance	7.50
Program Management	7.33
Equipment Test	6.78
Materials/Purchased Parts	6.45
Prototype Manufacturing	5.87
Design	5.33
Analysis	3.86
Product Support	3.84
Production Engineering	3.33
Financial Management	3.17
Contract Management	1.33
Value Engineering	0

3. <u>Specifications as Impact Barriers</u>

Many of the Government requirements and specifications that are typically imposed on a design and development program were observed, as noted in Chapter IV, to be barriers to effective warranty impact. The questionnaire responses indicated several major requirements and specifications that contractors would like to have altered or waived. The following were most frequently mentioned:

- MIL-E-5400P, General Specification for Airborne Electronic Equipment

- MIL-STD-781, Reliability Tests
- MIL-STD-785, Reliability Programs
- MIL-STD-810, Environment Qualification Tests
- MIL-STD-454, General Requirements for Electronic Equipment
- MIL-STD-883, Test Methods and Procedures for Microelectronics
- MIL-M-38510, General Specifications for Microcircuits
- MIL-STD-275, Criteria on Printed Circuit Construction
- MIL-STD-704, Aircraft Electric Power Characteristics
- MIL-Q-9858, Quality Assurance and Engineering.

Contractors also listed generic classes of requirements and specifications that should be changed.

- Configuration management specifications
- GSE specifications
- Quality assurance and control specifications
- Reliability demonstration specifications
- Maintainability demonstration specifications
- Methods of collecting and evaluating field malfunction reports
- Parts selection criteria and standard parts lists
- ECP control
- Non-standard parts approval
- Reprocurement data packages.

The basic rationale offered by the contractors for seeking relief or elimination of some of the above specifications barriers is that if a contractor is to be ultimately responsible, through a warranty, for the maintenance of his equipment, then he should be allowed the freedom to design, test, and produce equipment the way he wants. Contractors said that the performance guarantee of a warranty negates the need for many of the thousands of applicable specifications by assuring the purchaser that he will get the required functional performance without detailed specification of internal design details or development processes.

C. CORRELATION ANALYSIS OF CONTRACTOR RESPONSES

Throughout the study analyses, an attempt was made to determine if a relationship existed between contractor response and program status, Service sponsor, competitive environment, or other contractor or program characteristics.

Table 19 below summarizes the data used for these analyses. The aggregate impact for all program elements is presented together with two complementary subsets consisting of those program elements representing activities directly related to development program conduct and those of indirect influence. The data suggest that contractors also weighted these two categories differently.

Tables 20 and 21 illustrate some of the more important contractor subsets that were examined for correlation to or departure from the aggregate and direct program element impacts. The F-16 contractors, for example, reported an average impact similar to the total sample, except for the *actual* case, in which the F-16 contractors were essentially operating under *beginning* conditions. The advanced "3," consisting of those contractors associated with the three programs in the production stage (ARN-118 Tacan, ARC-164 radio, APN-209 altimeter), reported a higher average impact for each condition than did the total sample. However, a statistical comparison of the sample means and variances did not indicate that the impact reported by this group was significantly different from that reported by the others. Other distinctions that are apparent in Tables 20 and 21 include the higher average impact reported by Air Force program contractors and the similarities in program impact between the averages of all program elements and the average of the direct program elements.

Tables 20 and 21 also show that differences exist among the average subset impacts under each condition, but that when the standard deviation is calculated and statistical analysis

Table 19. SUMMARY OF WARRANTY IMPACTS FOR CANDIDATE CONTRACTORS

Sample	Warranty Application Condition	Impact Percentage, by Contractor Code																
		A	B	C	D	E	F	G	H	I	J*	K	L	M	N	O	P*	Average
All Program Elements	*Actual*	9.80	19.60	2.50	0.96	0.58	0	12.69	5.38	0	0	1.12	3.85	1.15	9.04	0	15.00	5.54
	Beginning	9.81	19.62	2.50	0.96	0.58	9.62	15.38	13.65	0	8.08	13.08	3.85	-0.77	9.04	10.77	15.00	8.17
	Firm	10.00	19.62	2.88	0.96	0.58	9.62	30.00	14.62	0	--	15.19	8.85	6.73	10.77	13.27	15.00	10.38
	Spec. Rel.	2.69	19.62	3.65	0.96	0.58	0.96	0	15.00	4.23	8.08	9.23	0	-2.88	9.04	10.77	--	5.59
Direct** Impact P.E.	*Actual*	7.69	19.74	2.05	0.51	0	0	15.54	2.85	0	0	5.64	5.13	1.54	8.46	0	15.90	5.32
	Beginning	7.69	19.74	2.05	0.26	0	8.97	15.90	12.56	0	7.69	11.28	5.13	0	8.46	11.54	15.90	7.95
	Firm	9.74	19.74	2.05	0.51	0	8.97	30.00	13.85	0	--	14.62	11.54	6.67	10.77	14.87	15.90	10.62
	Spec. Rel.	3.85	17.18	2.82	0.51	0	-2.56	0	13.59	5.64	7.69	6.92	0	-3.08	8.46	8.97	--	4.67
Indirect Impact P.E.***	*Actual*	16.16	19.23	3.85	2.31	2.31	0	3.85	13.08	0	0	11.54	0	0	10.77	0	12.31	5.96
	Beginning	16.15	19.23	1.54	2.31	2.31	11.54	13.85	16.92	0	9.23	18.46	0	-3.08	10.77	8.46	12.31	8.75
	Firm	10.77	19.23	5.38	2.31	2.31	11.54	30.00	16.92	0	--	16.92	0.77	6.92	10.77	8.46	12.31	9.64
	Spec. Rel.	-0.77	26.92	6.15	2.31	2.31	11.54	0	19.23	0	9.23	16.15	0	-2.31	10.77	16.15	--	7.85

*Contractors J and P did not indicate impacts for all conditions.

**Includes all Program Elements from design through program management, as listed in Table 17.

***Includes all Program Elements from financial management through contract management, as listed in Table 17.

Table 20. SUBSET CORRELATION ANALYSIS: ALL PROGRAM ELEMENTS

Sample	Warranty Application Condition											
	Actual			Beginning			Firm			Spec. Relief		
	n	$\bar{x}$(%)	Std. Dev.	n	$\bar{x}$(%)	Std. Dev.	n	$\bar{x}$(%)	Std. Dev.	n	$\bar{x}$(%)	Std. Dev.
Total Sample	16	5.48	6.17	16	8.20	6.34	15	10.54	8.08	15	5.46	6.33
F-16 Contractors	6	8.14	8.04	6	8.14	8.04	6	9.01	7.77	5	5.42	8.11
Advanced "3" Contractors	5	7.08	4.28	5	10.23	6.49	5	15.46	8.81	5	6.08	7.34
Sample Less F-16	10	3.88	4.47	10	8.23	5.58	9	11.56	8.52	10	5.49	5.74
Air Force Programs	10	7.84	6.52	10	8.94	6.93	10	11.23	9.22	9	6.09	7.04
Army Programs	4	2.13	3.25	4	5.72	6.69	4	8.13	5.93	4	2.07	5.11
Prod. Improvements	4	5.67	3.37	4	8.75	6.67	4	11.83	3.92	4	7.60	7.51
Adv. Technology	12	5.42	6.99	12	8.01	6.52	11	10.07	9.22	11	4.69	6.04

Notes: n = number of contractors.

$\bar{x}$ = average reported impact (percent).

Table 21. SUBSET CORRELATION ANALYSIS: DIRECT IMPACT PROGRAM ELEMENTS

Sample	Warranty Application Condition											
	Actual			Beginning			Firm			Spec. Relief		
	n	$\overline{x}$(%)	Std. Dev.	n	$\overline{x}$(%)	Std. Dev.	n	$\overline{x}$(%)	Std. Dev.	n	$\overline{x}$(%)	Std. Dev.
Total Sample	16	5.32	6.51	16	7.95	6.34	15	10.62	8.25	15	4.67	5.87
F-16 Contractors	6	8.08	8.20	6	8.08	8.20	6	9.49	8.13	5	5.33	7.06
Advanced "3" Contractors	5	6.80	5.56	5	9.64	6.02	5	15.18	8.85	5	5.18	6.70
Sample Less F-16	10	3.66	5.01	10	7.87	5.45	9	11.37	8.73	10	4.33	5.58
Air Force Programs	10	7.74	7.11	10	8.74	7.07	10	11.36	9.38	9	5.73	6.23
Army Programs	4	1.92	2.56	4	5.13	5.85	4	7.69	5.84	4	0.45	4.60
Product Improvements	4	4.62	3.08	4	8.08	5.65	4	11.48	3.61	4	6.47	6.98
Advanced Technology	12	5.55	7.41	12	7.91	6.79	11	10.30	9.54	11	4.01	5.65

Notes: n = number of contractors.
$\overline{x}$ = average reported impact (percent).

is attempted, these differences are not statistically significant. The subset impacts are characterized more by their similarities than by their differences.

Attempts to discern additional significant groupings based on reported impacts were unsuccessful. It is postulated that other factors are responsible for portions of the contractor responses and that those factors are either random in application or more subtle than those explicitly addressed.[1]

D. IMPACT MOTIVATION AND CHANGE IMPLEMENTATION

The research findings thus far have demonstrated that changes are occurring during design and development as a result of warranty considerations. At the same time, there are barriers that prevent greater impacts from occurring. If some of those barriers were removed, a significant change in development program effort would possibly occur.

This section identifies some of the motivations behind the potential impacts that have been identified and the steps contractors believe could be taken to implement changes in the typical electronics subsystem design and development program.

1. Risk and Uncertainty: The Primary Motivators

There is no question that the primary motivation for contractors to implement changes during design and development is to reduce future product experience risk. Information is sought that will reduce risk in the following areas:

- Initial field reliability
- Field reliability growth
- Probable failure modes
- Operational environment

[1]The reader is directed to the discussion in Chapter VII for the identification of additional factors that were found to influence warranty application and impact.

- Unit-production costs
- Economic escalation effects
- Possibility of induced failures
- Expected logistics system experiences.

The most frequently mentioned area of risk was operational reliability prediction for production units. This area and the risks associated with pricing replacement units or consignment spares years into the future combine to yield large financial risks that cannot entirely be quantified through development actions.

2. Reported Ways to Reduce Risks

Several methods were suggested by the contractors to help reduce risks. It has already been found that changes in warranty decisionmaking and the removal of a number of barriers would permit contractors to change their development program efforts to better quantify their risks. Another commonly reported approach is to expand the development pilot production phase (or low-rate initial production) such that some operational reliability and performance data can be obtained prior to warranty pricing. Listed below are other proposed actions that were recommended.

(1) Defer warranty price commitment until adequate technical and performance data exist.

(2) Develop procedures whereby Government can budget for and negotiate multi-year contracts.

(3) Specify performance rather than design parameters to suppliers.

(4) Do not price or negotiate during competitive phase.

(5) Extend the development phase to allow sufficient time for consideration of design options: structure an intensive post-development test program, incorporating field tests, to give the contractor and Government assurance and data prior to entering an RIW contract.

(6) Delete induced failures from contractor responsibility under warranty conditions.

(7) Define specific aircraft environments more precisely.

(8) Establish pilot production runs.

(9) Allow more performance-reliability trade-offs.

(10) Price options after prototype flight testing.

(11) Allow for renegotiation on first warranties after field experience data have been gathered and evaluated.

(12) Define specific environmental and operational applications.

(13) Conduct additional cost analyses of repair costs with varying failure modes.

The above list of contractor recommendations was augmented by questionnaire responses to several questions that focused on specific areas of effort needed to reduce risk. The most common response was a desire for longer and more realistic test programs. Examples of areas in which additional testing was recommended were--

(1) Flight testing.

(2) Formal reliability improvement-corrective action program.

(3) Operational-type testing in development.

(4) Accelerated-life testing.

(5) Mock-up testing.

(6) More burn-in type testing.

(7) Scheduled tests from initial production.

(8) More realistic reliability testing.

Based on the contractor responses, the greatest change would be implemented in the area of reliability demonstration testing to reduce, as much as possible, the uncertainties associated with predicting future field reliability. Changes would also be implemented in prototype or pilot production programs to provide test data on equipment that most closely resembles the production configuration and quality.

E. FINDINGS

The potential impact of warranties on the candidate development programs was investigated and quantified under three postulated conditions of warranty application. In addition, the factors influencing the impacts were evaluated, potential areas of program change were identified, and correlation of individual responses with contractor and program characteristics was attempted.

1. Potential Development Program Impact When Warranty Option Terms and Conditions are Known at the Beginning of Engineering Development

It was found that, for the aggregate contractor sample, the total average development program impact would represent an 8.2 percent increase in effort if warranty option terms and conditions were known at the beginning of engineering development. This represented a 50 percent increase in impact over that currently attributed to the prospect of warranties in the candidate programs. The major absolute increases in effort were predicted in areas of data and reports, materials/purchased parts, analysis, equipment test, and design. The areas of greatest impact change (leverage) were found to be value engineering, prototype manufacture, production engineering, and equipment test. If those program elements receiving an impact other than zero were considered, there was no appreciable change in impact on development effort over the actual candidate cases.

2. Potential Development Program Impact When Warranty is a Firm Requirement

It was found that a firm warranty requirement would result in an absolute increase in effort of 10.5 percent, which represented a 90 percent increase over the impacts presently experienced, on the average. Major functional areas affected were

prototype manufacturing, production engineering, design, and quality assurance. Program management was the area receiving the highest absolute increase in effort--14 percent. If only those program elements receiving an impact other than zero were analyzed, an absolute 15 percent increase in effort was estimated, which represented a 22 percent increase in effort over the present programs. Highest areas of impact included data and reports, program management, production engineering, and materials/purchased parts.

3. Potential Development Program Impact Under Specification Relief

It was found that if non-critical specifications and standards were relaxed, contractors believed that the development program efforts could be accomplished more efficiently than in the previous two cases, such that an average nominal 5.6 percent increase would be experienced. This is essentially the same change in effort as presently experienced. If only those program elements receiving an impact other than zero are considered, the decrease in effort is even greater, with the average percentage increase in effort declining from 12.4 percent to 9.9 percent. Data and reports, quality assurance, program management, and equipment test were the key areas in which decreases in effort were projected.

4. Correlation of Contractor Responses

It was found that certain contractors consistently reported greater increases in development program effort than others over all conditions examined. For those contractors reporting a warranty impact other than zero, the estimated impact on the candidate development program averaged 12.4 percent. The reported impacts for the beginning, firm, and specification relief conditions were 12.8, 15.1, and 9.9 percent, respectively.

Except for the *actual* case, this contractor subset reported an average impact 60 percent higher than the total aggregate sample. Attempts to correlate this group of contractors with other contractor characteristics were unsuccessful.

5. Impact Motivation and Change Implementation

It was found that the greatest motivation for changes in the engineering development program was the desire to reduce financial risk and uncertainty associated with field reliability prediction and future product cost. The changes driven by these motivations were reported to be widespread; more extensive test programs (not necessarily more expensive) and expansion of prototype or pilot production programs to permit additional testing were the major reported changes.

VI

THE IMPACT OF WARRANTIES ON CANDIDATE EQUIPMENT DESIGNS

The improvement of equipment reliability through changes in design is a key objective of warranties. This chapter examines some of the changes in design that occurred as a result of warranty considerations and the requirements that drove those changes. The previous chapters reported an average development program impact of from 5-9 percent increase in design effort; accordingly, corresponding impacts were found in the candidate product designs.

This chapter focuses on the product of the design effort--a black box having certain design features, partly as a result of the warranty requirements. Based on contractor interviews and the responses to the research questionnaire, specific design impacts have been categorized into five areas for analysis:

- Contractually required items
- BITE-automatic test equipment
- System architecture
- Sensors, indicators, and protective circuits
- Design redundancy and parts selection for higher inherent reliability.

The major design impacts are summarized in Table 22.

A. CONTRACTUALLY REQUIRED DESIGN IMPACTS

Our research found several warranty provisions that led directly to design impacts by requiring the inclusion of certain features in the products. Tamper-proof seals, for example, had to be incorporated in equipment box designs so that unauthorized

Table 22. REPORTED WARRANTY-INDUCED DESIGN CHANGES

Design Change	Type*	Requirement for Change	No. of Contractors Reporting
Optimized Circuit/Board Partitioning	C	Ease of Maintenance and Fault Isolation	5
Radiation Indicators	D	Induced Failure Protection	1
Expanded Built-In Test	B	Fault Isolation and False-Removal Protection	6
Shock Indicators	D	Detection of Mishandling	1
Thermal Indicator	D	Induced Failure Protection	3
Special Go/No-Go Test Circuits	B	Fault Isolation	1
Expanded Information Tag	A	Back-up Measurement of Operating Hours	2
Automatic Fault Isolation Circuitry	B	Ease of Fault Isolation	4
Hardwire Connectors	E	Greater Reliability	1
Expanded Automatic Test Equipment	B	Ease of Maintenance	1
Voltage Spike Indicators	D	Induced Failures	1
More Expensive Elapsed-Time Indicator	D	Operating-Time Measurement	3
System Design for Accessibility	C	Improved Maintainability	1
Component Selection for High Reliability	E	Improved Reliability	2

*A-Contractually Required Items
B-Built-In-Test or Automatic Test Equipment
C-System Architecture
D-Sensors, Indicators, Protective Circuits
E-Design Features for Higher Inherent Reliability

entry or repair could be easily detected. The use of a seal is intended to reduce tampering, which can range from attempts at minor repairs to extensive cannibalization.

Warranty markings were also required to advise users that an equipment warranty is in effect, thereby warning the user not to void the warranty by attempting unauthorized repairs. Labeling units to allow the logging of information, such as installation-removal dates, aircraft flying hours, and serial number, has also been required under warranty clauses.

Elapsed-time indicators (ETI) were usually required by contract to verify the actual equipment operating hours. This requirement is critical because the empirical parameter, equipment operating hours, enters into several key cost-sensitive provisions of warranty clauses.

B. BITE-AUTOMATIC TEST EQUIPMENT

The major responsibility of a contractor under a warranty is to repair all faulty equipment returned by the customer. Since the contractor is responsible for the repair costs, he should be motivated to take steps in the design of his equipment to reduce those expenses. One approach is to "design in" higher inherent reliability so that the calculated equipment MTBF is sufficiently high (see Section E).[1] Another approach is to provide for determining the failure mode of a failed unit even before it arrives at the plant so that appropriate spares can be available and other maintenance preparations taken. These actions would reduce the MTTR and associated cost-to-repair.

A related item of expense to contractors is RTOK items--returned equipment that subsequently is found to be working correctly. The checkout process for this equipment can be

[1]"Designing in" reliability most often consists of selecting component parts with higher reliability ratings or designing circuits with redundant, fail-safe features.

expensive--significantly higher than the $100 reimbursement for RTOKs cited in some warranty contracts. It is therefore to the contractor's advantage to reduce the number of RTOKs.

The observed design impact in this area is an increased emphasis on built-in test equipment and automatic test equipment. These impacts can range from including such items as go/no-go testers or externally viewed failure flags, to designing extensive automated test equipment, either for field or contractor use. The basic purpose of the test equipment is to aid in fault verification, isolation, and diagnosis, and to assist in intermittent failure detection and verification, thereby reducing MTTR and RTOKs.

The impact on test equipment design caused by requirements for fault isolation and diagnosis is an important consideration for contractors, since most equipments, even if meeting the specified MTBF, will fail once or twice during the time frame of a multi-year RIW contract and will be returned to the contractor for repair. Contractors noted in our interviews that the design for BITE is closely related to the maintenance level (e.g., LRU, SRA, module) for which it is intended.

C. SYSTEM ARCHITECTURE

The system architecture element of the design process was also found to be influenced by the maintenance level for which the equipment is designed. Many design features can be employed to enhance contractor repair and thereby significantly lower MTTR and the corresponding cost-of-repair.

The circuit partitioning among boards, cards, and modules can be arranged in a manner to better suit the use of the contractor's factory-based test equipment. At a higher maintenance level, the design of a set of autonomous LRUs negates the requirement to ship an entire failed unit back to the factory.[1]

[1]In many complex systems, each LRU must be "trimmed" or specifically tuned for the rest of the system and therefore is not an autonomous unit.

The accessibility of LRUs and SRUs is a design feature also receiving increased attention.

Warranty considerations were found to affect contractor make-buy decisions in the area of maintaining spares levels. In one candidate equipment, for example, alignment was critical to meeting performance requirements. The contractor could either purchase the complete assembly (already aligned) or purchase the parts and assemble and then align them. The consideration of having to furnish an expensive spare (the aligned subassembly purchased from vendors) convinced the contractor to assemble this component himself to reduce his potential spares cost under the warranty, even though the purchased aligned assembly might be preferable in performance.

D. SENSORS, INDICATORS, AND PROTECTIVE CIRCUITS

Contractors can employ a series of design strategies to monitor the operating environment of their equipment in the field. Of particular concern is the thermal environment, but the correct application of primary electrical power, vibration and shock conditions, and radiation hazards also have to be considered.

In some cases, the contractor can obtain an "induced failure" exclusion from the warranty if the operational environment experienced by the equipment can be shown to be outside specifications. In such cases, an indicator of thermal overload or an over-under voltage indicator can help assess responsibility for the equipment failure.

In other cases we examined, the lack of proper environmental conditioning is *not* necessarily cause for a failure exclusion. In these cases, the contractor provided sensors linked to protective circuitry in order to protect his equipment. For example, a monitoring sensor can be designed to shut off the equipment if there is a deficiency in the cooling air input to

the equipment. Upon a post-operation inspection, a flag can then be read to determine that this condition obtained. Even if protective circuitry is not used, indicators of "out-of-spec" conditions are helpful in failure diagnosis. Other design features in use to prevent potential environmental conditioning problems included the use of low-power electronics and conduction-cooled electronics to reduce dependence on cooling air.

E. DESIGN FOR HIGHER INHERENT RELIABILITY

We expected that the impact of warranties on the design process would include a number of design changes to improve the inherent reliability of the equipment under development. Our research found that this was not an important impact. Few contractors reported the use of component or circuit redundancy[1]--a classic technique for improving reliability.

The only impact that was reported was a greater tendency to use proven integrated circuits (ICs). Vendors were being asked to show examples of existing successful applications in addition to the usual "brochuresmanship" estimates of reliability. Several contractors also cited derating of parts and components as becoming more common.[2]

F. FINDINGS

Changes in product design as a result of the warranty requirements were reported by the contractors. Warranty requirements led to design changes in areas of tamper-proof seals, warranty markings and labeling, and elapsed-time indicators.

[1]It is recognized that the existence of DTC goals for unit-production costs tends to inhibit such design actions.

[2]Derating involves using a part at an electrical-environmental operating level less than the maximum for which it was designed. For example, a part may be rated at a certain maximum temperature and derating would mean using that part only in applications of 25 percent lower temperatures.

More sophisticated designs for BITE and automated test equipment were used by contractors to reduce the MTTR and number of RTOKs. The system architecture was also changed to enhance contractor repair. Sensors, indicators, and protective circuits were becoming important design ingredients in order to monitor the equipment operating and handling environment. Finally, the use of proven components and derating techniques to improve inherent reliability was also reported.

VII
ADDITIONAL ISSUES RELATING TO WARRANTY IMPACTS

The research efforts expended during this study, and particularly the numerous meetings with both Government program officers and contractor personnel, uncovered a number of additional issues and problem areas that can also affect the application and impact of reliability warranties. Many are linked to other problems needing solution. Some can be trivial in major programs or system developments, but can become major roadblocks at the subsystem level. Some require political or institutional solutions. All need more investigation and more illumination.

A. CONTRACTOR MOTIVATION FOR INCREASED RELIABILITY

Many of the contractors and Government personnel we interviewed believe that a major failing of the present electronics system and subsystem acquisition process is that it permits the contractor to proceed into production without sufficient confidence or assurance that predicted field performance will be achieved. Current proof-test programs are not considered adequate; often the primary motivation for contractors is to "pass the test" rather than to test and fix equipment rigorously and repeatedly until it has been thoroughly evaluated.[1]

The prospective exercise of warranty options by the Government was expected to change this "pass the test" attitude.

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[1]It is not so much a case of poor test design as it is of inadequate relevant-failure interpretation, non-realistic test environment, use of handmade prototype test equipment, and skilled contractor maintenance personnel. In many development and demonstration programs, the pressures to announce the successful completion of the equipment development often take precedence over a realistic assessment of program status.

But our research found little change in traditional contractor motivation. Many of those interviewed believe that unless the penalties (not necessarily cost) outweigh the advantages of "passing the test" and unless steps are taken to provide the time and funds necessary to develop complex equipment properly, there will be no real contractor motivation for ensuring that design reliability is transferred through development to field operations.[1]

B. GOVERNMENT CREDIBILITY FOR WARRANTY SUCCESS

Throughout our investigations on warranty impact, the question of Government credibility was frequently raised. In large measure, we found this question to be founded on the contractor's real or perceived observation that project officers were merely going through policy-directed motions without any real interest in negotiating and implementing warranties. Frequently, warranty options were observed to be unpopular with Government program officers because the details of the warranty were not fully understood, were difficult to negotiate, were almost impossible to substantiate on the basis of cost alone, were a financial burden on scarce procurement funds, and would ultimately be supervised and directed by another functional organization within the Services.

In addition to perceiving Government hesitancy over warranties, some contractors believe that, if the Government is truly serious, they should be allowed more freedom to design and develop equipment in a way that minimizes their warranty

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[1]Somehow, almost all newly developed equipment manages to "pass the test" during reliability demonstration, acceptance, and other performance verification or validation tests. Test waivers, definitions of relevant failures, contingency provisions, and similar test modifiers are all used to demonstrate the successful test accomplishment, usually on prototype hardware--which may differ substantially from production hardware.

risks. Unfortunately, as discussed in Chapter IV, in an environment of tight budgets and constrained program schedules, such freedom is not easily achieved.

Thus, many contractors feel that it is "business as usual" and have discounted the possibility of having to stand behind a product warranty that might ultimately result in great financial loss.[1]

C. COMPETITIVE ENVIRONMENT

As in all programs, the competitive environment influences the actions of the individual contractor firm throughout the equipment acquisition phase. During our research, we found many instances in which competitive efforts to capture the market, perpetuate the product line, or acquire new technology influenced decisions during engineering development.[2] Too often, warranty options were priced so as to remain competitive, without a full appreciation of later development and production impacts. Similarly, development programs were often planned and proposed to meet customer demands for schedule compression and low cost. In this environment, the impact of future warranty obligations is latent until a full appreciation of future obligations and financial risk is acquired. Under these circumstances, the relationship of equipment performance and contract requirements to design and development program planning as well as the relationship of price to actual estimated costs, including

[1]Many contractors were surprised that the first major warranty contract (Air Force Tacan) was actually executed with the RIW-guaranteed MTBF provisions. Some still believe that sufficient legal remedies exist to preclude major losses on the Tacan or similar programs.

[2]This is not to be construed as a criticism of competition, which probably leads to more efficient management. However, the power of a monopsonistic market can force sellers to take otherwise unacceptable risks to remain in the market.

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[2]This is not to be construed as a criticism of competition, which probably leads to more efficient management. However, the power of a monopsonistic market can force sellers to take otherwise unacceptable risks to remain in the market.

risk coverage, can be heavily biased in order to respond to market forces.[1]

D. PREDICTION OF FIELD RELIABILITY

Prediction of field reliability has been mentioned throughout this study as a source of negotiating difficulty, a consideration that can impact on the equipment design and development program, and as the major uncertainty in warranty pricing or risk assessment. This issue has also had a peripheral impact on development programs by establishing new data requirements for the benefit of future warranty programs.

As the need for an accurate estimate of a new product's field reliability, both initially and as a function of operating time, became critical, the need for better field data on the reliability experience of past systems was also recognized. Subsystem contractors discovered that they had poor or incomplete data bases for their own equipment and also for other similar equipment presently in the field.[2] Moreover, much of their data was of questionable utility since information on important variables, such as operating time, application, and cause of failure, were not readily available from Government maintenance reports.[3] We found that this void in the basic information required to determine historical relationships between demonstrated and operational reliability has created a need to develop a permanent data base on past and present equipment reliability

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[1] I.e., risk is discounted, performance is estimated optimistically, and the warranty option price becomes a marketing tool.

[2] A great deal of valuable data acquired during reliability demonstration and similar test programs had simply been discarded by the contractors after a few years.

[3] This is a key point. The Services have developed maintenance reporting systems, not reliability reporting systems.

so that future reliability prediction can be made with less uncertainty and greater realism.[1]

E. DIFFERENCES BETWEEN PROTOTYPE AND PRODUCTION EQUIPMENT

A number of the potential impacts identified in Chapter V are related to expansion of present development programs so that more testing can be accomplished on equipment that is as close to production configuration as possible. Many of the contractors we interviewed believe that pilot production units should be produced, tested, and placed into service *prior* to pricing a warranty. In their experience, prototype equipment, assembled and tested under laboratory conditions, performs differently (usually better) from equipment assembled and acceptance tested in quantity production.

The significance of the differences observed between prototype and production equipment should not be underestimated. Together with uncertainties associated with the field operating environment, the uncertainties associated with the performance of production equipment have been reported to be responsible for much of the reliability degradation experienced with operational equipment.[2] And, as we have observed, knowledge of field reliability degradation is key to quantifying contractor risks and to pricing warranty options.

These factors could form the basis for a significant development program impact. Pilot production or low-rate initial production programs might be included as a key ingredient in

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[1]Whether accurate reliability experience extrapolations can be made in view of major changes in technology is an issue yet to be investigated. We have made an implicit assumption that past relationships between design and demonstrated and realized reliability are valid indicators of future experience. This hypothesis needs research, especially in the electronics technology area.

[2]After differences in failure definition and reporting practices have been taken into account.

the reliability development and demonstration process. Production decisions and warranty commitments could also be delayed until the results of the initial production unit performance are known. These events would undoubtedly have cost, schedule, and contractual impacts. We believe that an analysis of the costs and benefits of implementing these development changes on selected equipments would be worthwhile.

F. DESIGN-TO-COST VS. DESIGN-FOR-WARRANTY

As noted earlier, a dichotomy can arise whenever contractors are asked to design to meet firm unit-production costs goals, set by standards of acquisition affordability, and then are asked to design equipment with guaranteed operational reliability. Our research found that important trade-offs affecting equipment design, production cost, and field reliability can be made if the DTC goals are mated to reliability warranty considerations in the initial phases of the engineering development program. Adding a warranty option after DTC goals have been established is counterproductive and inhibits the potential beneficial impacts of internalizing reliability and maintainability responsibility to the contractors.[1]

G. TECHNOLOGICAL INNOVATION VS. DESIGN CONSERVATISM

There is not much doubt that the possibility of warranty obligations does affect the contractor's risk-taking posture. One area of impact was observed in the use of advanced technology during equipment design. Despite many potential advantages to the utilization of advanced components, circuit

[1] The counterargument to these perceived difficulties is that the Government is only asking the contractors to stand behind the specification requirements they have already accepted; therefore DTC and warranties should not be incompatible if realistic and achievable reliability-maintainability goals have been accepted.

designs, and assembly techniques, the use of unproven, nonstandard, or low production-volume parts was reported by many to be inhibited. The ultimate impact was believed to be a tendency toward design conservatism on warrantable equipment or more thorough design proof-testing during the advanced development stage.

H. RETURN-ON-INVESTMENT CONSIDERATIONS

Warranties have, on occasion, been described as a good business venture with built-in incentives for greater contractor profitability. Possible benefits include the future profit potential as a result of the increased reliability, the availability of multi-year warranty funds at equipment delivery rather than on an annual basis, and the opportunity to sustain equipment manufacture and maintenance during the warranty period.

To achieve these monetary and other returns, most contractors we interviewed reported than an additional investment beyond the Government's present level of investment in engineering development programs would be required to reduce the risk factor. Among the candidate programs, examples of this type of investment were seen in the form of company-funded development test and demonstration programs, qualification efforts for new components and parts, revised material control and quality assurance procedures, additional work toward adapting prototype designs for production, and the establishment of pilot production prior to production contract award. The return on this type of investment during the design and development stage was reported to be acceptable only if (a) the contractor wins the production competition, (b) the government exercises the warranty option, and (c) the predicted equipment field reliability and maintainability are approached in practice.

At the present time, many contractors we interviewed believe that the probability of all these events occurring is such that a reasonable return will not be achieved.

I. THE COST IMPACT OF RELIABILITY WARRANTIES

Our research was concentrated on identifying design and development program impacts; therefore, we did not explicitly examine the cost impact of warranties for either development or equipment production.[1] Based on our research, however, a cost impact can be expected in most cases for additional development effort. This cost would have to be included with the equipment warranty price to estimate the full cost of an equipment warranty.

Table 23 presents a summary of the estimated warranty cost impact using assigned percentage weightings for the direct development program categories and the impact percentages presented in Chapters IV and V.[2] This table illustrates that, if only the program elements of the contractors reporting impacts other than zero are analyzed, the direct cost impact would be 11 percent under *actual* or *beginning* warranty application conditions, 15 percent if the warranty requirements were *firm* at the beginning of engineering development, and 8 percent if *specification relief* were permitted. If all program element impacts (including zero) are used for analysis, the expected cost impact would be 5 percent for the *actual* case, 8 percent for the *beginning* case, 11 percent for the *firm* case, and 5 percent for the *specification relief* case. The indirect cost elements, materials and purchased parts, financial management, value engineering, and contract management, have not been included; those costs were considered to be assignable to overhead or indirect accounts.

The actual costs of achieving predicted field reliability for any of the candidate programs are not known at this time.

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[1]For each program, the relative cost contribution by functional element would be necessary to calculate the R&D cost impact from data reported by the contractors. This presents an interesting topic for future investigation.

[2]The assigned percentage weightings have been selected based upon the experiences of the investigators. Individual development programs could differ significantly depending upon the nature of the development task.

Table 23. ESTIMATED WARRANTY COST IMPACT ON SELECTED ENGINEERING DEVELOPMENT PROGRAM ELEMENTS

Development Program Category	Assigned Percent of Total Development Program Effort	*Actual* Percent Change		*Beginning* Percent Change		*Firm* Percent Change		*Firm* Percent Change With Spec. Relief		*Actual* Total Cost Impact (Percent)		*Beginning* Total Cost Impact (Percent)		*Firm* Total Cost Impact (Percent)		*Firm* Total Cost Impact With Spec. Relief (Percent)	
		I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Design	15	8.89	5.00	9.77	7.94	15.00	11.00	8.50	5.67	1.47	0.75	1.17	1.19	2.25	1.65	1.28	0.85
Analysis	10	11.10	6.94	12.41	9.31	14.17	11.33	10.18	9.33	1.11	0.69	1.24	0.93	1.41	1.13	1.02	0.93
Prototype Manufacture	13	4.25	2.13	5.82	4.00	9.09	6.67	1.71	0.80	0.55	0.28	0.76	0.52	1.18	0.87	0.22	0.10
Equipment Test	22	10.63	5.37	11.67	8.75	15.15	11.11	7.22	4.33	2.34	1.18	2.57	1.93	3.33	2.44	1.59	0.95
Quality Assurance	10	9.69	4.84	11.75	7.34	14.09	10.33	7.08	2.83	.97	0.48	1.18	0.73	1.41	1.03	.71	0.28
Program Management	10	17.14	7.50	17.00	10.63	19.09	14.00	14.29	6.67	1.71	0.75	1.70	1.06	1.91	1.40	1.43	0.67
Product Support	5	11.39	6.41	11.54	9.38	12.31	10.67	9.32	6.83	.57	0.32	.58	0.47	.62	0.53	.47	0.34
Production Engineering	5	13.00	4.06	15.71	6.88	17.22	10.33	15.00	7.00	.65	0.20	.79	0.34	.86	0.52	.75	0.35
Data and Reports	10	18.33	6.88	13.33	7.50	20.00	12.00	5.71	2.67	1.83	0.69	1.33	0.75	2.00	1.20	.57	0.27
TOTAL	100	--	--	--	--	--	--	--	--	11.20	5.34	11.26	7.92	14.97	10.77	8.04	4.74
All Other Development Program Elements	--	14.14	5.74	14.52	8.62	14.99	9.35	12.69	6.62	--	--	--	--	--	--	--	--

Notes: *Actual* = reported impact on candidate engineering development program.
Beginning = potential impact if terms and conditions of warranty option were fixed at beginning of engineering development.
Firm = potential impact if warranty were firm requirement at the beginning of engineering development.

Case I impact calculated based on only those contractors reporting impacts other than zero.
Case II impact calculated based on all contractors reporting impacts, including zero.

However, we believe a valid warranty cost-benefit study would have to identify and estimate the non-recurring direct and indirect costs, as well as the recurring costs of warranties, in order to assist in the warranty decision process.

J. THE SUBSYSTEM CONTRACTING ENVIRONMENT

The unique features of the subsystem acquisition environment have been documented before, especially in those instances when contract requirements were dominant forces in subsystem contractor behavior.[1] Often, subsystem contractors are the subcontractors of major prime contractors, as is the case for the F-16 avionics. And while the subcontractors may be obligated to meet or exceed the major provisions of their prime contractor's contract with the Government, they have little leverage on their many suppliers to pass along critical contract risks and obligations.

This situation of risk containment prevailed for all the candidate subsystem contractors examined in this study. Not one contractor reported that he was able to pass reliability warranty guarantees on to his suppliers. This left the subsystem contractor in a position of weakness, because he was unable to ensure his major cost components or spread the risk among several subcontractors. This factor, among others, was important in establishing risk-averting management behavior and in explaining the uncommon concern over the risk implications of the warranty obligations that we observed during the interviews.

K. LEGAL ENFORCEABILITY

In the course of our research, we encountered frequent

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[1]For a discussion of design-to-cost acquisition policies and the subsystem contractor environment, see C. David Weimer, *The Application of Design-to-Cost Acquisition Policies to Selected Electronics Subsystem Development Programs*, IDA S-459 (1975), pp. 67-73.

discussions about the potential for "gaming" the warranty option such that potential risks are not encountered in actual practice or, if they are, the contract can be modified or voided.[1] If the contractor, under a warranty contract situation, believes that he can minimize or limit his potential loss, then his basic incentives are affected from early in the design stage through production and deployment of the equipment. If the risk-factored profit (expected value of financial gain) is small and the potential penalty or loss limited, then there will be little real incentive to expend additional time and effort early in the development program. One contractor stated that it may be more profitable to spend resources in pursuit of legal remedies than in product improvement. Moreover, the contractor's negotiating leverage increases with each additional unit delivered to the field, particularly because he will be dealing with Service management who did not participate in the early contract warranty formulation.

We also encountered mention of the ultimate legal enforceability of warranty penalties often enough in our research to believe that the warranty impact on the design and development program does, in fact, depend to some degree upon the contractor's assessment of both the Government's policy credibility and the warranty's eventual legal enforceability.[2]

L. CONCLUDING REMARKS

This chapter highlighted a number of issues that either individually or collectively could influence the equipment design

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[1]It is not the intent to discuss the strategies and methodologies of "gaming" in this report. This topic is presented only for its observed and potential impact on the design and development process as an exogenous impact agent.

[2]For example, a possible legal position supported by a posture of unconscionability resulting from the market power of the Government during negotiations was mentioned during our research interviews.

and development process.[3] We could not ascertain whether many or all of these issues came into play in all the candidate programs. However, since they were recurring topics of discussion, initiated primarily by contractor personnel, they have been raised here for further research and debate. Some of these issues could be determining factors affecting the outcome of equipment warranty programs.

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[3]Preventing an impact is viewed as an important influence, also.

VIII

SUMMARY OF FINDINGS AND CONCLUSIONS

A. SUMMARY OF FINDINGS

The research effort yielded a number of significant findings related to the application and impact of warranties on the candidate programs. These findings, derived from the questionnaire responses and the many contractor interviews, are summarized by major topic below.

1. Warranty Requirements and Their Application

Our investigations into the warranty requirements and their application provided findings in areas of contract requirements, contractor development environment, equipment maturity, and warranty negotiation.

Most of the programs investigated contained multiple warranty obligations or options geared to the achievement of specified operational reliability. The requirement details were similar for all programs examined. The reliability improvement warranty and guaranteed MTBF options were patterned after the Air Force Tacan contract, and the requirements for meeting Service logistics support cost targets were similar to those negotiated for the Air Force UHF radio program.

Equipment warranties covering operational performance for time periods exceeding two years were found to be new contract requirements for the candidate contractors, most of whom lacked previous military warranty experience. The warranties therefore represented a completely new contractual commitment for the contractors.

Contractors did not usually negotiate the detailed terms and conditions of their warranty obligation until negotiation of the production contract. This situation was found to inhibit important design trade-offs during the engineering development program.

Most (eleven of sixteen) of the contractors described their equipment as a "new technological development" rather than a product improvement over a previous model. The risk associated with predicting the ultimate field reliability of the equipment was found to be increased because of the lack of relevant field data on previous equipment.

Difficulties or critical areas during warranty requirements negotiation were reported in eleven major categories. Measurement of field reliability, definition of relevant failures, and warranty price were the critical negotiating areas most frequently identified by the contractors.

2. Impact on Candidate Development Programs

The overall impact of warranty requirements on the candidate development programs, in terms of the increase in development program effort, was reported to be small. An average impact of 5.5 percent increase in effort was recorded based on all sixteen questionnaire responses. The development program functional elements receiving the greatest impact were contract management, program management, design analysis, data and reports, and financial management.

Several requirements were identified as influencing the execution of the development program. Explicit requirements for equipment seals, elapsed-time indicators, and environmental and operational data directly influenced the functions of design, prototype manufacture, and report preparation, respectively. Implicit equipment performance and maintainability requirements for MTBF, MTTR, and TAT influenced efforts in program, contract, and financial management as a part of the overall risk assessment.

Major barriers to additional program impacts were also identified. The major constraints, as reported by the contractors, were the uncertainty of warranty requirements, the shortage of additional development funds, the constrained development program schedule, preset unit-production cost goals, and inflexible equipment performance and product specifications.

3. Impact on Product Designs

The impact of warranty options on equipment design was reported to be minor, except for contract-imposed requirements for box seals, elapsed-time indicators, and warranty labels. A small impact was reported in the areas of built-in test circuitry or other means of failure isolation, such as test equipment accommodation.

The primary barrier to design impacts appeared to be the requirement to design equipment suitable for both Service organic maintenance and contractor maintenance.

4. Potential Impact on Candidate Development Programs

Three warranty application conditions that could lead to increased warranty impact were identified and investigated during the research. These conditions were: (1) negotiation of warranty terms and conditions at the beginning of engineering development, (2) elimination of the option status of warranty contract requirements, and (3) greater specification flexibility.

The responses to the IDA research questionnaire indicated that the overall development program effort would have been increased from 5.5 percent to 8.2 percent if the negotiation of warranty terms and conditions had been accomplished prior to the beginning of engineering development; similarly, the program effort would have been increased to 10.5 percent if the option-decision uncertainty had been removed. If greater specification

flexibility were also permitted, total additional effort would increase nominally, to 5.6 percent. However, the areas for increased effort would be different from those in the current programs.

5. Correlation of Contractor Responses

Certain contractors consistently reported greater increases in development program effort than did other contractors over all conditions examined. For those contractors reporting a warranty impact other than zero, the estimated impact on the candidate development program averaged 12.4 percent. The reported impacts for the *beginning, firm,* and *specification relief* conditions examined in Chapter V were 12.8, 15.1, and 9.9 percent, respectively. Except for the *actual* warranty application case, this contractor subset reported an average impact that was 60 percent higher than the total aggregate sample.

Attempts to correlate this group of contractors with other contractor characteristics were unsuccessful. Attempts to identify relationships between contractor response and program status, Service sponsor, competitive environment, major system application, and other characteristics were also unsuccessful. No identifiable rationale for specific contractor behavior could be found.

6. Additional Issues Relating to Warranty Impacts

The following additional issues relating to warranty impacts were identified during the research effort:

- Contractor Motivation for Increased Reliability
- Government Credibility for Warranty Success
- Competitive Environment
- Prediction of Field Reliability
- Differences Between Prototype and Production Equipment

- Design-to-Cost vs. Design-for-Warranty
- Technological Innovation vs. Design Conservatism
- Return-on-Investment Considerations
- Cost Impact of Equipment Warranties
- Subsystem Contracting Environment
- Legal Enforceability of Warranty Contracts

These issues, either individually or in the aggregate, were reported to influence contractor behavior during engineering development by helping to create a greater impact or by presenting barriers that precluded further impact.

B. CONCLUSIONS

Based on the findings of the limited research effort, the following conclusions can be drawn regarding warranty impacts *on the candidate subsystems* examined during the study.

1. Warranty Application Has Been Uncertain and Imperfect

The application of warranties to the candidate electronics subsystem development programs was made in an environment of uncertainty created by the experimental nature of the warranty acquisition policy, the lack of previous contractor experience with warranties, the advanced technological status of the equipment, and the lack of definitized warranty requirements during development. This environment and contractor uncertainty about the Government's ultimate exercise of the warranty option resulted in an imperfect application of warranty techniques. Because of these conditions, we believe the warranty experiments represented by the candidate subsystems may not be conclusive indicators of the success or failure of the Government's warranty policy.

2. Warranty Options Are Not Yielding Design and Development Incentives for Improved Reliability

Given the uncertainties surrounding the application of warranties and the observed impact on the candidate programs, it is concluded that warranty options are not changing the equipment design and development process in ways that would either significantly improve the inherent reliability of the equipment or provide necessary additional information to contractors regarding expectations of future equipment field reliability. Presently, the candidate warranty options can be better characterized as fixed-price options for future maintenance of production equipment.

3. The Potential Exists for Increased Warranty Impact

There is a potential for increased beneficial warranty impacts on the equipment design and the development process if uncertainties and barriers surrounding warranty application are removed. Elimination of the optional nature of present warranty programs, for example, appears to be an important step. The increased impact can be achieved most efficiently if maximum allowable specification relief accompanies changes in warranty policy. Realization of the increased impacts could necessitate longer development schedules and additional development funds because of the increased effort involved. However, we believe that this investment would be cost-effective over a subsystem's life cycle if equipment reliability and availability were thereby significantly improved.

4. Warranty Options Have Captured Management Attention

The interviews and questionnaire responses have demonstrated that warranty options have attracted the attention and concern of Service and contractor management. This concern has been prompted by the great uncertainties surrounding the candidate

program outcomes. Steps to translate this concern into positive action for improved equipment reliability are potentially available and are outlined as "Guidelines for Warranty Policy Development and Application" in Chapter IX.

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IX

GUIDELINES FOR WARRANTY POLICY DEVELOPMENT AND APPLICATION

The findings derived from Government and contractor interviews and the data retrieved during this research study support several guidelines for continued warranty policy development. These guidelines, presented below, are steps that OSD and the Services should consider to improve the application of warranties to electronic subsystem development programs. In particular, these guidelines are aimed at enriching the design and development process and providing greater leverage over life-cycle costs and better operational performance for the development funds expended.

A. OPTIMAL SCHEDULING FOR WARRANTY DECISIONS

In order to achieve maximum benefits from equipment warranties, the maintenance philosophy for the candidate equipment should be established by the completion of the equipment's advanced development stage, i.e., before DSARC II. The option process for exercising warranties should be discarded as counterproductive to optimizing equipment design and to achieving increased equipment reliability and maintainability through the development process.

B. WARRANTY REQUIREMENTS DEFINITION

The specifications and requirements for future equipment warranties should be negotiated early in the equipment development program, preferably during negotiation of the engineering development contract. These requirements should be treated the same as equipment design or performance specifications.

C. INTEGRATION OF WARRANTIES WITH DESIGN-TO-COST PROGRAMS

The application of warranties to programs that already contain design-to-cost goals should initiate a reassessment of the production cost targets to minimize the sum of future acquisition and operational costs. A formal process should be established to enable contractors and Service project officers to revise unit-production cost goals if such a change can be justified on the basis of reduced life-cycle costs.

D. SPECIFICATION FLEXIBILITY

Specification flexibility for non-critical requirements assumes a role of even greater importance when contractors are required to assume additional responsibilities for equipment performance. Thus specification flexibility should be an integral part of each warranty procurement.

E. RELIABILITY DATA AND PREDICTIVE MODELS

To aid in improving reliability prediction, retrieval of current and past field reliability data on all generic equipment suitable for warranty application should be continued. Efforts also should be increased to predict more accurately future field reliability from demonstration test data. These initiatives should be taken with help from, and feedback to, the industrial contractor sector.

F. DEVELOPMENT FUNDING AND SCHEDULE FLEXIBILITY

Preparations for meeting equipment warranty guarantees may require additional development time and funds. The Defense Department should recognize this possibility and take steps to ensure that additional time and money are available.

X

TOPICS FOR ADDITIONAL RESEARCH

Most research studies uncover a number of questions that are not answered by the original effort, and this study is not an exception. Many questions that were surfaced during our investigation demand research attention if the application experience with warranties is to mature. The more important subject areas for additional research are listed below; all are presented in question form for the benefit of prospective investigators.

- How cost effective are equipment warranties when all direct and indirect costs and benefits are considered?
- Have warranties affected the engineering change proposal (ECP) process and application experience?
- What impact will widespread use of warranties exert on the Services' logistics organizations and operations?
- What is the cost value of uncertainties in the prediction of future field reliability and maintainability?
- What are the historical trends and supporting methodologies for predicting reliability?
- Do warranty considerations inhibit technological innovation during design and development?
- What has been the actual field operating experience to date with the multi-year warranties?
- Are warranties for parts of subsystems feasible? What are possible ramifications of a partially warranted weapon system?

Appendix A

TASK ORDER T-125: RELIABILITY IMPROVEMENT
WARRANTY IMPACT ASSESSMENT

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BOULEVARD
ARLINGTON, VIRGINIA 22209

TASK ORDER FOR WORK TO BE PERFORMED
BY
INSTITUTE FOR DEFENSE ANALYSES

TASK ORDER T-125 DATE: ____________

You are hereby requested to undertake the following task:

1. TITLE: Reliability Improvement Warranty Impact Assessment

2. BACKGROUND: Reliability Improvement Warranties (RIW) and other reliability guarantees offered by equipment manufacturers have proven to be effective ways for improving equipment operational reliability in commercial airline applications. Based upon the commercial experience with avionics equipment during the past ten years, the purchase of RIWs with equipment is now a standard and cost-effective practice for airline avionics procurement.

Extended-duration warranties for military application were initiated by the Navy in 1969 with the acquisition of a Lear-Seigler airborne gyro assembly. Subsequent development of the concept has led to widespread consideration of RIW options for avionics equipment in all Services.

RIWs have also become important ingredients in the Design-to-Cost (DTC) acquisition process where total life-cycle costs are critical considerations. In a recent study, IDA has documented the application of RIW options to several electronics subsystems.[1] This investigation indicated that the incorporation of RIW options or reliability guarantees into equipment acquisition programs could significantly influence the design and development process and the developed equipment. The impact of RIW options upon equipment acquisition was identified as a topic needing further study.

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1 IDA Study S-459, "The Application of Design-to-Cost Policies to Selected Electronics Subsystem Development Programs", June 1975.

3. OBJECTIVE: The objective of this task is to analyze the impact of RIW options upon the design and development process and the resulting systems and subsystems.

4. SCOPE: IDA is asked to investigate and analyze Service experiences to date in the planning and execution of development programs containing provisions for RIW options. The programs selected for study with DDR&E concurrence will consider as candidates those electronic subsystems previously investigated for Design-to-Cost policy application and selected avionics subsystems being developed for the multinational F-16 Air Combat Fighter (ACF) as well as others appropriate to this task. The depth of the analysis will depend upon the extent to which appropriate data and information on the systems can be obtained. For each program (within the scope of the available data), the requirements of the RIW option will be documented, and the impact of these requirements upon development program planning, equipment design, development testing, development program cost and schedule, and equipment production cost and performance, will be analyzed.

5. SPECIFIC TASKS:

1. Identify and document for each candidate program the requirements for RIWs which were established and imposed upon the program during the development phase.

2. Document and analyze the impacts of the reliability specification and RIW requirements upon the design and development process in terms of development program scope, cost and schedule, and product design, performance and cost, form, fit and function, and use of Government Furnished Equipment (GFE).

3. Based upon data and insights developed, identify steps that OSD and the Services can take in the development process to assure that newly-developed items can transition to production with warranty provisions which assign commensurate risks to both the Government and contractors.

6. SCHEDULE: The first phase of this task will be limited to 45 days for the purpose of identifying and selecting the candidate programs. Thereafter informal progress report briefings are requested at three-month intervals during the task effort. A Draft Final Report is requested on 1 October 1976.

7. ODDR&E COGNIZANCE: Cognizance of this task is within the Office of the Assistant Director (Planning), ODDR&E.

8. SCALE OF EFFORT: A maximum of 15 man-months of effort, including use of consultants is authorized for this task.

9. REPORT DISTRIBUTION AND CONTROL: All report distribution will be controlled by the office of technical cognizance.

10. SPECIFIC INSTRUCTIONS AND LIMITATIONS: None. Changes in scales of effort will not be made without the consent of ARPA. A "need-to-know" is hereby established in connection with this task and access to U.S. and foreign program information in the field of this Task is authorized for participating personnel and such supervisory and advisory personnel as deemed necessary. Department of Defense support, such as access to classified documents and publications, security clearances, and the like, necessary to complete this Task, will be obtained through the cognizant ODDR&E office.

George H. Heilmeier
Director

ACCEPTED: Alexander H. Flax
President, IDA

DATE: 10 October 1975

Appendix B

AFSC MEMORANDUM: SUPPORT FOR TRI-SERVICE RELIABILITY AND SUPPORT INCENTIVES WORKING GROUP

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE SYSTEMS COMMAND
ANDREWS AFB, WASHINGTON, D.C. 20334

SD

3 DEC 1975

Support for Tri-Service Reliability and Support Incentives Working Group

ASD/YP/YPE/YPL/RWV/YHK

ESD/OCN

1. AFSC is participating in a Tri-Service Reliability and Support Incentives Working Group recently chartered by the Acting Assistant Secretary of Defense (I&L) and DDR&E. The prime purposes of this Group are to develop improved policies and procedures for motivating contractors to produce reliable systems and to enhance the transfer of lessons learned in Reliability Improvement Warranties and Life Cycle Costing.

2. The Institute for Defense Analyses (IDA) has been tasked to support the Tri-Service Working Group in achieving its objectives. IDA will study our experience with the various incentive techniques and their impact upon the development of electronics subsystems. The IDA study director is Dr. David Weimer, AUTOVON 225-1382.

3. Your office is requested to cooperate with the IDA study team in providing access to the appropriate contractors and program data.

FOR THE COMMANDER

SIGNED

MELVIN F. [illegible], Colonel, USAF
Assistant [illegible]

Cy to: AFLC/AQNLE

Appendix C

OSD MEMORANDUM: TRI-SERVICE RELIABILITY AND SUPPORT INCENTIVES WORKING GROUP

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

4 NOV 1975

MEMORANDUM FOR Director of Defense Research and Engineering
Assistant Secretary of Defense (I&L)
Assistant Secretaries of the Military Departments (R&D)
Assistant Secretaries of the Military Departments (I&L)

SUBJECT: Tri-Service Reliability and Support Incentives Working Group

The tri-Service group which has been formed as a result of our memorandum of 5 September 1975 (same subject) has received excellent support from the Services. The first meeting of the working group was held 7 October 1975 and as you can see from the attached minutes and action plan there are a significant number of critical tasks to be accomplished. Continued emphasis will be placed on identifying and developing guidelines that will have an early pay-off. The working group activities will be focused on tasks related to: (1) Risk/Cost Analysis, (2) Application of RIW's, and (3) Other Reliability and Support Cost Incentives.

As a result of your favorable support of this endeavor, assurance has been received from both Army and Navy that $55,000 each will be made available to Air Force for the Tri-Service RIW Data Base and Analysis Tasks. It is anticipated that the Services will identify their task requirements by 6 November 1975, the Air Force will translate these requirements to a firm statement of work by 19 December 1975 and a contract could be awarded during February 1976.

The next meeting of the working group will be held 6 November 1975. At that time the Service working group members are to present how the independent analysis of RIW applications is conducted in response to the ASD(I&L) memorandum of 16 September 1975, (Subj: Reliability Improvement Warranty (RIW) Guidelines).

It appears that production phase RIW requirements will influence the research and development (R&D) process and result in improved equipment reliability. The full R&D impact of these requirements has yet to be assessed and is therefore a task area of the working group. Accordingly,

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the Institute for Defense Analysis (IDA) has been tasked to observe, record, and analyze the impact RIWs have on the development process for those programs previously examined for Design to Cost (DTC) policy application. Also, they are to identify other equipment developments where RIW can be implemented to affect the development process and where impact can be assessed. For the IDA project leader, Dr. C. David Weimer, to perform effectively during the study, access to information from Service staff, program manager, and contractor/subcontractor offices is essential. With your concurrence the Service staff members of the working group will be considered as the points of contact for the purposes of this study.

Your support of the working group and the application of RIW's to reduce support cost and improve field reliability of equipment is appreciated.

R E Berry

ROBERT E. BERRY
Deputy Director
(Policy & Planning)

JACQUES S. GANSLER
Deputy Assistant Secretary of Defense
(Materiel Acquisition)

Attachment

Appendix D

IDA RESEARCH QUESTIONNAIRE

IDA
INSTITUTE FOR DEFENSE ANALYSES
400 ARMY-NAVY DRIVE, ARLINGTON, VIRGINIA 22202 • TELEPHONE (703) 558-1000

To: Distribution

Subject: Reliability Improvement Warranty Questionnaire

The Institute for Defense Analyses (IDA) has been directed by DDR&E (Office of the Deputy Director for Policy and Planning) to investigate the introduction of Reliability Improvement Warranties (RIWs) and other life-cycle cost guarantees into recent defense electronics acquisitions. The focus of the IDA effort is identification of the impact that these new initiatives may have upon future equipment development programs and equipment design.

Recent IDA research in defense electronics acquisition (IDA Study Report S-459) has revealed that requirements for equipment warranties or life-cycle cost guarantees can be coupled to the design of the equipment and the conduct of the engineering development program. Many questions or problem areas associated with implementing operational guarantees are best addressed by taking appropriate actions during the design and development process thereby reducing risk and uncertainty for both defense contractors and the Government.

The purpose of the IDA research task is to identify both beneficial as well as dysfunctional impacts of equipment operational performance guarantees upon the electronics development process. The task is also aimed to delineate potential design and development barriers which impede the effective application of these guarantees.

To achieve these objectives, nineteen development contractors representing fourteen candidate electronics programs, as shown in Attachment A, are being interviewed and are requested to complete the attached questionnaire for their particular program. Additional interviews will subsequently be scheduled to retrieve the questionnaire and discuss specific candidate program issues. The responses of all contractors will be summarized; all data will be coded to prevent disclosure of specific programs or contractors.

The output of the research effort will be an identification of changes which can be made during the design or development process to favorably affect the successful negotiation and implementation of product field-performance guarantees. Potential barriers to achievement of lower life-cycle cost and increased field reliability will also be identified for Government requirements review.

Copies of the resulting study report will be sent to each respondent as well as all candidate program offices.

Reliability Improvement Warranty Questionnaire
Page 2

If you have questions or need clarification regarding the questionnaire or the IDA study effort, you are encouraged to contact the undersigned at (703) 558-1843.

Thank you for your cooperation and participation in this project.

Sincerely,

C. David Weimer
Project Director

Attachments

(A) List of candidate subsystems and contractors.
(B) RIW Impact Questionnaire

ATTACHMENT A

CANDIDATE SUBSYSTEMS FOR RIW IMPACT ASSESSMENT STUDY

No.	Subsystem	Service	Status	Govt. PM	Contractor(s)	Contractor Location
1.	ARN-118 TACAN	USAF	PROD	ESD	Collins General Dynamics	Cedar Rapids, Iowa San Diego, Calif.
2.	ARC-164 UHF Radio	USAF	PROD	ASD	Magnavox Collins RCA	Ft. Wayne, Indiana Cedar Rapids, Iowa Camden, N.J.
3.	APN-209 Abs. Altimeter	USA	PROD	ECOM	Honeywell Hoffman	Minneapolis, Minn. El Monte, Calif.
4.	ASN-128 Doppler Nav.	USA	Eng. Dev.	ECOM	Singer-Kearfott Teledyne/Ryan	Little Falls, N.J. San Diego, Calif.
5.	DTP EW Suite	USN	Eng. Dev.	NAVELEX	Hughes Raytheon	Fullerton, Calif. Santa Barbara, Calif.
6.	B-1 ECM Suite	USAF	Eng. Dev.	ASD	Cutler Hammer Boeing Aerospace	Deer Park, Long Island Seattle, Washington
7.	F-16 Radar	USAF	Eng. Dev.	ASD	Westinghouse Hughes	Baltimore, Md. Culver City, Calif.
8.	F-16 Heads-Up Display	USAF	Eng. Dev.	ASD	Marconi-Elliot	England (Chamblee, Ga.)
9.	F-16 HUD Electronics	USAF	Eng. Dev.	ASD	Marconi-Elliot	England (Chamblee, Ga.)
10.	F-16 Inertial Nav.	USAF	Eng. Dev.	ASD	Singer-Kearfott	Little Falls, N.J.
11.	F-16 Fire Cont. Comp.	USAF	Eng. Dev.	ASD	Delco Div. G.M.	Goleta, Calif.
12.	F-16 Flight Cont. Com.	USAF	Eng. Dev.	ASD	Lear Siegler	Santa Monica, Calif.
13.	F-16 Radar E/O Disp.	USAF	Eng. Dev.	ASD	Kaiser Aerospace	Palo Alto, Calif.
14.	F-16 Radar E/O Disp. Elect.	USAF	Eng. Dev.	ASD	Kaiser Aerospace	Palo Alto, Calif.

INSTITUTE FOR DEFENSE ANALYSES

RESEARCH QUESTIONNAIRE

THE IMPACT OF RELIABILITY IMPROVEMENT WARRANTIES UPON ELECTRONICS EQUIPMENT DESIGN AND DEVELOPMENT

CANDIDATE PROGRAM: ____________________

PROJECT PROPRIETARY INFORMATION

THE IMPACT OF RELIABILITY IMPROVEMENT WARRANTIES
UPON
ELECTRONICS EQUIPMENT DESIGN AND DEVELOPMENT

INTRODUCTION

This questionnaire is designed to solicit the experiences and the opinions of selected defense contractors who are currently or have recently engaged in development programs containing requirements for future equipment Reliability Improvement Warranties (RIWs). The primary purpose of the questionnaire is to identify the actual or potential impact that RIWs or RIW options have upon the development process and the developed equipment. A subsidiary, but critically important, objective of this questionnaire is to identify those elements of current electronics development programs which inhibit or act as barriers to the success of RIW implementation.

While it is the intent of this questionnaire to derive information acquired on a specific program managed by your company, the results of the questionnaire will be combined in such a manner as to conceal all program identification. Your response will be held in strictest confidence; no correlation or identification will be made in the reported results between responses and specific programs. Data from each of the nineteen selected contractors will be held by IDA as Company-Proprietary information.

This questionnaire is divided into four parts. Part A is designed to provide general background information concerning your company and your past experience with product warranties. Part B solicits information concerning your recent or current development program and the equipment under development. Part B also solicits your opinions and suggestions for improvements in the development process. Part C addresses the construction of a proposed engineering development program under assumed

conditions that an RIW is not optional but is a pre-planned condition for future equipment procurement. Part D is an attempt to obtain specific examples of the RIW impact upon development programs and equipment.

Most of the questions contained in this questionnaire can be answered by simply checking the appropriate box or by supplying a few words relative to your particular program. However, it is recognized that all of the key issues surrounding RIWs and the development process may not be identified by the questions. Therefore, sufficient space has been provided for your use to amend or elaborate upon the questions asked. <u>This type of "feedback" is very important to this study and is specifically encouraged.</u>

A. **BACKGROUND INFORMATION:**

1. Title or position of respondent. ____________________

2. Briefly indicate past development or production programs which contained warranties or warranty options. ____________________

____

____

3. The candidate program can be characterized as:

/_7 A Product Improvement (Over A Previous Model)

/_7 A New Technological Development

/_7 ____________________

4. As of January 1, 1976, the status of the candidate product development program was:

/_7 10% Complete /_7 25% Complete /_7 50% Complete

/_7 Completed

5. The topic of an RIW warranty was first formally introduced to the candidate development program:

/_7 With the Development RFP /_7 Prior to PDR

/_7 Prior to CDR /_7 Prior to Qual. Testing or Prototype Demonstration

/_7 With the Production RFP

6. At what point were the terms and conditions of the RIW option negotiated?

/_7 Development Contract Award /_7 CDR

/_7 Production RFP /_7 Production Contract Award

/_7 Not Yet Negotiated

7. Indicate the most critical areas for negotiation you believe are contained in your RIW option.

/_7 Definition of Relevant Failures

/_7 Turn-Around Time

/_7 Consignment Spares Provisions

/_7 Warranty Price

/_7 Measurement of Field Reliability

/_7 ECP Procedures

/_7 Economic Escalation Provisions

/_7 Configuration Control Provisions

/_7 Contractor Data and Reports

/_7 Warranty Time Period

/_7 Other (Specify) ______________________________

____

____

8. What is (or was) the approximate dollar value of the candidate equipment development program? $__________.

B. IMPACT OF RIW OPTION ON THE CURRENT OR RECENT DEVELOPMENT PROGRAM

1. Listed in the table below are the functional elements of a typical electronics development program. In the first column you are requested to identify those elements which were actually influenced by the presence or possibility of the RIW option and estimate the impact in terms of incremental effort or program scope change. In the second major column you are requested to indicate your best estimate of what the impact of the RIW option would have been if the terms and conditions had been negotiated prior to start of the engineering development program. Assume for both cases that the warranty is to be a priced option and that Government organic maintenance requirements were also imposed upon the program. Do not hesitate to add to the functional list or make other appropriate modifications.

The choice of response for each functional element has been divided into six possibilities ranging from a moderate decrease in effort to a significant increase in total effort. Assume that a "small" increase or decrease represents approximately a 10 percent change, a "moderate" increase or decrease a 20 percent change, and a "significant" increase represents anything over 25 percent additional effort.

TABLE 1

DEVELOPMENT PROGRAM ELEMENT	ACTUAL IMPACT UPON CANDIDATE PROGRAM						ESTIMATED IMPACT WITH RIW OPTION AT THE BEGINNING OF ENGINEERING DEVELOPMENT					
	MODERATE DECREASE	SMALL DECREASE	NO CHANGE	SMALL INCREASE	MODERATE INCREASE	SIGNIFICANT INCREASE	MODERATE DECREASE	SMALL DECREASE	NO CHANGE	SMALL INCREASE	MODERATE INCREASE	SIGNIFICANT INCREASE
DESIGN												
CIRCUIT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CARD AND BOARD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODULE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SRA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LRU OR FLU	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SYSTEM ARCHITECTURE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BUILT-IN TEST	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
TEST EQUIPMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GROUND SUPPORT EQUIPMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRODUCTION TOOLING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ANALYSIS												
THERMAL	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
STRESS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EMC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ENVIRONMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FAILURE-MODE-EFFECTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RELIABILITY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MAINTAINABILITY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRODUCIBILITY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
OPTIMUM REPAIR LEVEL	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
COST-PERFORMANCE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MATERIALS AND PURCHASED PARTS												
PART SELECTION	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
VENDOR SCREENING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
COST ESTIMATING AND PRICING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PROTOTYPE MANUFACTURE												
COMPONENT PROCUREMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CARD OR BOARD ASSEMBLY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODULE ASSEMBLY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BOX OR CHASSIS ASSEMBLY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FUNCTIONAL TEST AND CHECKOUT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EQUIPMENT TEST												
PART/COMPONENT ACCEPT. TEST	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BREADBOARD TESTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BRASSBOARD TESTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EQUIP. PERFORMANCE DEMON.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EQUIPMENT ENVIRONMENTAL TESTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EQUIPMENT RELIABILITY TESTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

TABLE 1 (Continued)

	ACTUAL IMPACT UPON CANDIDATE PROGRAM						ESTIMATED IMPACT WITH RIW OPTION AT THE BEGINNING OF ENGINEERING DEVELOPMENT					
	MODERATE DECREASE	SMALL DECREASE	NO CHANGE	SMALL INCREASE	MODERATE INCREASE	SIGNIFICANT INCREASE	MODERATE DECREASE	SMALL DECREASE	NO CHANGE	SMALL INCREASE	MODERATE INCREASE	SIGNIFICANT INCREASE
QUALITY ASSURANCE												
QUALITY ENGINEERING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
INSPECTION	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
IN-PROCESS MONITORING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
TEST MONITORING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PROGRAM MANAGEMENT												
COST TRACKING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FINANCIAL MANAGEMENT												
PRODUCTION COST ANALYSIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ECONOMIC ESCALLATION ANALY.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LIFE-CYCLE COST ANALYSIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PROGRAM FINANCIAL CONTROL	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRODUCT SUPPORT												
SPARES REQUIREMENTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CONTAINER DESIGN & ANALY.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
STE/AGE DESIGN & ANALY.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LOGISTICS PLANNING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRODUCTION ENGINEERING												
PRODUCIBILITY ANALYSIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MANUFACTURING ENGINEERING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
VALUE ENGINEERING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DATA AND REPORTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CONTRACT MANAGEMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
OTHER (PLEASE LIST)												
____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2. Discussions with a small sample of participating contractors indicate that there exist a number of barriers which may prevent many beneficial development program changes from occuring. In the list of typical program or product design constraints presented below, please indicate those which you believe constrain changes which would be beneficial to your future RIW option. Once again, you are encouraged to contribute additional information.

Program Constraint	No Effect	Minor Constraint	Major Constraint
a. Production Cost Goal			
b. Development Schedule			
c. Development Funds			
d. Performance Specifications			
e. Reliability Goals			
f. Military Specifications:			
Standard Parts			
Reliability Prediction			
Environmental Testing			
Configuration Control			
Engineering Changes			
Quality Assurance			
g. Data Rights			
h. Source Selection			
i. Report Requirements			
j. Other			

3. From the above list, name the program requirement which you feel presents the greatest barrier to designing and developing equipment suitable for RIW application.

____

4. The requirements associated with RIW options demand changes be made in the design of the equipment. Examples of such changes are elapsed-time indicators, tamper-proof box seals, and warranty identification decals. You are requested to list other design changes which you have made (or would like to have made) in response to specific RIW option requirements.

Design Change		RIW Requirement or Reason for Change
____________________	...	____________________
____________________	...	____________________
____________________	...	____________________
____________________	...	____________________
____________________	...	____________________
____________________	...	____________________
____________________	...	____________________
____________________	...	____________________
____________________	...	____________________
____________________	...	____________________

5. In view of your experience to date, name any specific changes you would propose in your next development program if the requirement for a priced RIW option was known at the beginning of the Engineering Development program.

____

____

____

6. In your opinion, what specific measures can either the Government or their contractors take during development to reduce the risks inherent in contracting for a multi-year Reliability Improvement Warranty.

7. Which elements of the RIW option do you believe represent the greatest amount of pricing uncertainty?

C. IMPACT OF RIW AS A FIRM CONTRACT REQUIREMENT

It is the intent of this part to determine the potential impact of RIW requirements upon the equipment development process when it is known at the outset of engineering development that the equipment will be procured with firm RIW obligations. The entire warranty maintenance concept is to be the responsibility of the contractor. The Government will, however, have the option to terminate or renew the warranty at the end of the initial warranty period which should be assumed to be five years. The details of the logistics support and maintenance program, together with the proposed cost of an RIW, will be considered a part of the competitive production contract source selection criteria.

1. As in Part B above, you are asked to indicate in the following table the impact of an RIW requirement upon the development process. The effects of two separate operating conditions are again solicited; the first set of responses assumes other program and product specifications continue to be imposed while the second response matrix is for the situation where <u>all</u> specifications and requirements are flexible and negotiable <u>except</u> for critical performance, cost, and reliability requirements. As before, your additional comments or areas of impact are solicited.

TABLE 2

	EXPECTED IMPACT WITH FIRM RIW REQUIREMENTS (NO SPEC RELIEF)						EXPECTED IMPACT WITH FIRM RIW REQUIREMENTS (FULL SPEC RELIEF)					
	MODERATE DECREASE	SMALL DECREASE	NO CHANGE	SMALL INCREASE	MODERATE INCREASE	SIGNIFICANT INCREASE	MODERATE DECREASE	SMALL DECREASE	NO CHANGE	SMALL INCREASE	MODERATE INCREASE	SIGNIFICANT INCREASE
<u>DEVELOPMENT PROGRAM ELEMENT</u>												
<u>DESIGN</u>												
CIRCUIT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CARD AND BOARD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODULE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SRA	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LRU OR FLU	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SYSTEM ARCHITECTURE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BUILT-IN TEST	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
TEST EQUIPMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GROUND SUPPORT EQUIPMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRODUCTION TOOLING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
<u>ANALYSIS</u>												
THERMAL	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
STRESS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EMC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ENVIRONMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FAILURE-MODE-EFFECTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
RELIABILITY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MAINTAINABILITY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRODUCIBILITY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
OPTIMUM REPAIR LEVEL	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
COST-PERFORMANCE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
<u>MATERIALS AND PURCHASED PARTS</u>												
PART SELECTION	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
VENDOR SCREENING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
COST ESTIMATING AND PRICING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
<u>PROTOTYPE MANUFACTURE</u>												
COMPONENT PROCUREMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CARD OR BOARD ASSEMBLY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODULE ASSEMBLY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BOX OR CHASSIS ASSEMBLY	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FUNCTIONAL TEST AND CHECKOUT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
<u>EQUIPMENT TEST</u>												
PART/COMPONENT ACCEPT. TEST	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BREADBOARD TESTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BRASSBOARD TESTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EQUIP. PERFORMANCE DEMON.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EQUIPMENT ENVIRONMENTAL TESTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EQUIPMENT RELIABILITY TESTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

TABLE 2 (Continued)

	EXPECTED IMPACT WITH FIRM RIW REQUIREMENTS (NO SPEC RELIEF)						EXPECTED IMPACT WITH FIRM RIW REQUIREMENTS (FULL SPEC RELIEF)					
	MODERATE DECREASE	SMALL DECREASE	NO CHANGE	SMALL INCREASE	MODERATE INCREASE	SIGNIFICANT INCREASE	MODERATE DECREASE	SMALL DECREASE	NO CHANGE	SMALL INCREASE	MODERATE INCREASE	SIGNIFICANT INCREASE
QUALITY ASSURANCE												
QUALITY ENGINEERING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
INSPECTION	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
IN-PROCESS MONITORING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
TEST MONITORING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PROGRAM MANAGEMENT												
COST TRACKING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
FINANCIAL MANAGEMENT												
PRODUCTION COST ANALYSIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ECONOMIC ESCALLATION ANALY.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LIFE-CYCLE COST ANALYSIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PROGRAM FINANCIAL CONTROL	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRODUCT SUPPORT												
SPARES REQUIREMENTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CONTAINER DESIGN & ANALY.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
STE/AGE DESIGN & ANALY.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LOGISTICS PLANNING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PRODUCTION ENGINEERING												
PRODUCIBILITY ANALYSIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MANUFACTURING ENGINEERING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
VALUE ENGINEERING	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DATA AND REPORTS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CONTRACT MANAGEMENT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
OTHER (PLEASE LIST)												
____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2. Assuming a firm RIW program requirement, list those major Government requirements and specifications which are typically imposed upon a design and development program <u>and</u> which you would either like to have altered or waived.

3. Identify any specific changes in equipment design or configuration which would occur as a direct result of knowing at the outset that contractor warranty provisions would be part of the production contract award.

(a)

(b)

(c)

(d)

(e)

4. What areas of new technology would you like to pursue (either on IR&D or company funds) to improve your competitive position in developing equipment for warranty service?

5. What steps do you believe the Government could take during the development stages of a program to help contractors optimize their designs for warranty.

6. What additional effort, if any, do you think might be pursued during development to increase confidence in future production equipment field reliability and reliability growth during the initial phases of deployment.

7. What additional significant changes in development program plans or product design can you identify if contractor maintenance was planned throughout the lifetime of the equipment.

D. CASE STUDY ANALYSIS

The preceeding sections have examined actual or anticipated design and development program impacts from a generalized program point of view. It is the intent of this section to document specific examples where the impact of the RIW option can be seen. One typical example for both the program and the product will be sufficient for our purposes.

1. Describe, for your recent or current candidate development program, a specific case where the requirement for an RIW option has made an impact or change in the development program. Describe the impact in terms of extra tasks, increased scope of work, increased costs, additional schedule time, etc. The RIW requirement which drove the change should also be identified.

2. Describe a change or innovation made to the design of the candidate equipment in response to a specific RIW requirement. Identify the requirement and describe the design or configuration change, including some estimate of the estimated production cost impact.

Appendix E

LIST OF GOVERNMENT AND CONTRACTOR INTERVIEWS

GOVERNMENT AND CONTRACTOR INTERVIEWS

Government Program Office	Interview Dates
USN, NAVELEX (DTP EW Suite)	18 December 1975
USAF, ESD (ARN-118 TACAN)	9 January 1976
USAF, ASD, (ARC-164 Radar)	12 January 1976
USAF, ASD, (B-1 ECM)	12 January 1976
USAF, ASD (F-16 SPO)	13 January 1976
USA, ECOM (APN-209 Altimeter)	30 January 1976
USA, ECOM (ASN-128 Doppler Navigator)	1 March 1976

Contractor	
Hughes Aircraft Corp. (Aerospace Sys. Div.)	3 November 1975
Hoffman Electronics (NAVCON Div.)	4 November 1975
Hughes Aircraft Corp. (Ground Systems Div.)	5 November 1975
Teledyne/Ryan Co.	6 November 1975
General Dynamics Corp. (Electronics Div.)	7 November 1975
Westinghouse Electric Co. (Defense & Electronics Div.)	14 November 1975
Teledyne/Ryan Co.	28 November 1975
Kaiser Aerospace Corp.	5 December 1975
Collins Radio Corp.	22 January 1976
General Dynamics Corp. (Ft. Worth Div.)	23 January 1976
Kaiser Aerospace Corp.	5 February 1976
Hughes Aircraft Corp. (Aerospace Groups)	9 February 1976
General Motors Corp. (Delco Div.)	10 February 1976
Hughes Aircraft Corp. (Ground Sys. Div.)	12 February 1976
Hoffman Electronics (NAVCON Div.)	13 February 1976
Hughes Aircraft Corp. (Aerospace Groups)	16 February 1976
Lear Siegler Corp.	17 February 1976
Westinghouse Electric Co. (Defense Div.)	9 March 1976
Singer-Kearfott Corp.	11 March 1976
Cutler Hammer Corp. (AIL Div.)	15 March 1976
Boeing Aerospace Corp.	23 March 1976
Raytheon Co. (Santa Barbara Div.)	25 March 1976
Teledyne/Ryan Co.	26 March 1976
General Dynamics Corp. (Electronics Div.)	29 March 1976
RCA Inc.	30 March 1976
Rockwell International Corp. (Collins Radio Div.)	31 March 1976
Minneapolis Honeywell (Defense Electronics Div.)	27 May 1976
Magnavox Co.	28 May 1976
Hoffman Electric Co. (NAVCON Div.)	1 June 1976
Hughes Aircraft Corp. (Ground Sys. Div.)	2 June 1976
Lear Siegler Corp.	2 June 1976
Hughes Aircraft Corp. (Aerospace Div.)	3 June 1976
Raytheon Co. (Santa Barbara Div.)	4 June 1976

Appendix F

ANNOTATED BIBLIOGRAPHY

ANNOTATED BIBLIOGRAPHY

1. *Airborne Electronic Equipment Lifetime Guarantee*, R. H. Myers and C. M. DeWitt, III, Hughes Aircraft Company, RADC-TR-69-363 (Griffiss Air Force Base, New York: Rome Air Development Center, 1969).

   Examines the feasibility of applying various types of lifetime guarantee plans to the procurement of avionics. Examines the practicality of plans and guarantee ramifications throughout system lifetime. F-106A system data were utilized.

2. "An Analysis of Decision Criteria for the Selection of F-16 Reliability Improvement Incentive Alternatives," Thomas R. Kogel and Nathan B. Mills, Jr., Air Force Institute of Technology thesis (Ohio: Wright-Patterson Air Force Base, 1975).

   Analyzes F-16 alternatives from a government-benefit point of view. Methodology is developed to compute significant costs to the government over the equipment operational lifetime for each alternative. The procedures and results of the methodology are demonstrated for two selected F-16 FLUs.

3. *Application of Design-to-Cost Acquisition Policies to Selected Electronics Subsystem Development Programs*, C. David Weimer, S-459 (Arlington, Va.: Institute for Defense Analyses, 1975).

   Analyzes DoD experience in applying design-to-cost acquisition policies to electronic subsystems. Fourteen subsystems representing three Services and involving 27 industrial contractors were investigated. Guidelines for future policy development derived from the findings were recommended in the areas of DTC subsystem program planning, prediction of production costs and equipment performance, reliability improvement warranties, and subsystem management.

4. *Application of Reliability Improvement Warranty (RIW) to DoD Procurements*, Dennis Jean Allen (Monterey, Calif.: Naval Postgraduate School, 1975).

Concludes that RIW may be a valuable tool for bring buyer-seller goals into agreement by transferring the management of costs to the seller.

5. *Application of the Commercial Airline Acquisition Methodology to Department of the Navy Electronic Equipment Acquisition,* L. J. Graham, Pub. No. 1313-01-1-1447 (Annapolis, Md.: ARINC Research Corp., 1975).

Includes comparative analyses of the airline acquisition method and the Navy acquisition method, development of a recommended acquisition policy, preliminary economic analysis, and recommendations for a pilot program.

6. *Audit Report--Subsystems Management,* Air Force Audit Agency, (1975).

Discusses warranty markings, storage of items under warranty, warranty repair, and information systems.

7. "Aviation Supply Office FFW/RIW Case History #2, Abex Pump," Oscar Markowitz, *Proceedings 1976 Annual Reliability and Maintainability Symposium,* Las Vegas, Nev., January 20-22, 1976 (New York: Institute of Electrical and Electronics Engineers, Inc., 1976).

Presents case history of a warranty application with a purely mechanical equipment.

8. *Avionics Reliability Study,* Lt. Col. Ben H. Swett, USAF, Phase I and II (Andrews Air Force Base, Camp Springs, Md.: Air Force Systems Command, 1973 and 1974).

Discusses the disparity between specified and operational MTBF of avionics equipment.

9. "(The) Change in DoD Electronics Acquisition," Jacques S. Gansler, Deputy Assistant Secretary of Defense (Materiel Acquisition), Address Before the 1972 Winter General Session of the Airlines Electronic Engineering Committee, Miami, Fla., December 12, 1974.

Discusses three changes in the approach to the acquisition process for DoD weapon and electronics systems--design-to-price, standardization, and holding the supplier more responsible for the field reliability of his equipment (warranty).

10. "Considerations for Effective Warranty Application," B. L. Retterer, *Proceedings 1976 Annual Reliability and Maintainability Symposium,* Las Vegas, Nev., January 20-22, 1976 (New York: Institute of Electrical and Electronics Engineers, Inc., 1976).

Reviews the several forms that a warranty can take. Outlines criteria for identifying potentially effective applications. Presents a method for evaluating the economic feasibility of a warranty.

11. "Contractor Performance/Warranties/Organic Support: The Failure Free Warranty Experience at ASO," Thomas L. Schanz, paper presented at Seminar on Interfaces and Relationships of Design to Cost, Integrated Logistics Support, Life Cycle Costing, Washington, D.C., May 14-15, 1974 (National Security Industrial Association, 1974).

Discusses the elements of the warranty, the mutual sharing of the risks and rewards, the estimate of reliability, and the real-life influences on that reliability.

12. "(A) Contractor View of Warranty Contracting," William J. Bonner, *Proceedings 1976 Annual Reliability and Maintainability Symposium,* Las Vegas, Nev., January 20-22, 1976 (New York: Institute of Electrical and Electronics Engineers, Inc., 1976).

Presents a set of typical warranty contract provisions and then proceeds to discuss the challenges offered to the contractor by those provisions.

13. *(A) Cost Effectiveness Study of Air Force vs. Contract Maintained Non-Tactical Radio Systems,* Gerald E. Bronnenberg (Maxwell Air Force Base, Ala.: Air University, 1972).

Compares the costs of contract nontactical radio maintenance with Air Force maintenance.

14. "Cost of Reliability Improvement," Avery H. Heuesh, *Proceedings 1969 Annual Symposium on Reliability,* Chicago, Ill., January 21-23, 1969 (New York: Institute of Electrical and Electronics Engineers, Inc., 1969).

Examines systematically the contributions of individual, independent methods for reliability improvement and computes their "efficiencies" using data from a number of major reliability programs.

15. "Designing for LCC," William H. Boder, *Defense Management Journal,* January 1976.

Discusses the Magnavox experience with LCC on their ARC-164 radio.

16. *(The) Development and Analysis of RIW and COD Provisions for the Air Combat Fighter (ACF) Aircraft,* G. Harrison, Pub. No. 1264-01-1-1370 (Annapolis, Md.: ARINC Research Corp., 1975).

Describes the chronology of events and the decision rationale in the evolution of life-cycle-cost controls for the air combat fighter. Includes "lessons learned" summary.

17. *Electronics-X: A Study of Military Electronics With Particular Reference to Cost and Reliability,* in 2 vols.,2: "Complete Report," Howard P. Gates, Jr., et al., R-195 (Arlington, Va.: Institute for Defense Analyses, 1974).

Identifies the current DoD and industrial policies, procedures, and practices in development, production, and operational support that most significantly influence the cost and reliability of military electronics. Recommends changes to reduce and control cost and to improve reliability. The report concentrates on five major,

high-impact areas: (1) data collection and feedback, (2) requirements, (3) competition and management options, (4) reliability enhancement, and (5) maintenance training. Numerous other areas are discussed, and detailed recommendations are made in regard to each.

18. *Evaluation of F-16 Subsystem Options Through the Use of Mission Completion Success Probability and Designing to System Performance/Cost Models,* A. M. Doman and A. G. Dunkerly, Air Force Institute of Technology thesis (Ohio: Wright-Patterson Air Force Base, 1975).

Analyzes F-16 subsystems and determines optional strategies for RIW, RIW/MTBF, and TLSC options in terms of mission completion success probabilities and costs.

19. "Factors on Balancing Government and Contractors Risk with Warranties," Russell R. Shorey, *Proceedings 1976 Annual Reliability and Maintainability Symposium,* Las Vegas, Nev., January 20-22, 1976 (New York: Institute of Electrical and Electronics Engineers, Inc., 1976).

Discusses the DoD background, new incentive techniques, warranty pricings, warranty application, and LCC implications.

20. "Failure Free Warranty--5 Year Results," R.P. Wilcox, *NAECON '74 RECORD* (New York: Institute of Electrical and Electronic Engineers, Inc., 1974).

Discusses the Failure Free Warranty (FFW) concept and concludes that the original program was a total success.

21. *Government Contract Warranties,* Government Contracts Monograph No. 2 (Washington, D.C.: George Washington University, 1961).

Includes four papers: (1) "Warranties under the General Law of Sales--Some Relationships to Government Contract Law," by John W. Whelan; (2) "Government Contract Warranties," by Frederick Sess; (3) "An Industry Attitude Toward Government-Required Warranty Clauses," by John F. Carr; and (4) "Army Contractual Warranties--The Quest for Quality," by Donald E. Miller.

22. "Government Depot Maintenance Warranties," Russell M. Genet, *Proceedings 1976 Annual Reliability and Maintainability Symposium*, Las Vegas, Nev., January 20-22, 1976 (Institute of Electrical and Electronics Engineers, Inc., 1976).

Discusses the concept of government depots' offering maintenance warranties.

23. *Government Depot Maintenance Warranties*, Don E. Hunt, Russell M. Genet, and Theodore Crosier, AGMC 74-019 (Ohio: Aerospace Guidance & Metrology Center, Newark Air Force Station, 1974).

Introduces the concept of government depot maintenance warranties and discusses their advantages and disadvantages, what a warranty might consist of, and how it might work.

24. *Guidelines for Application of Warranties to Air Force Electronic Systems*, Harold S. Balaban and Bernard L. Retterer, 1500-01-1-1451 (Annapolis, Md.: ARINC Research Corp., 1975).

Reviews basic types of warranty plans. Provides information on the applicability of various types, developing a set of terms and conditions, administrative procedures for developing and implementing a warranty, and evaluation procedures for monitoring warranty performance. A life-cycle cost model is presented. Includes a case study of the AN/ARN-118 TACAN set. Sample warranty provisions, a user's manual, and other reference material are also provided.

25. "Industry Application of Failure Free Warranty Techniques," Ralph P. Wilcox, presented at 8th Annual Joint Services Data Exchange Conference for Inertial Systems, held at Charles Stark Draper Laboratory, Cambridge, Mass., August 19-21, 1974.

Discusses both the general application of FFWs and 5-year results for the Lear Siegler gyro as a case study.

26. *Industry Sub Group Report on RAM Incentives and Warranties*, R. H. Waln, et al. (Washington, D.C.: American Defense Preparedness Association, 1975).

Reports on background information obtained from U.S. Army Electronics Command on methods and techniques for expanding use of RAM incentives and warranties.

27. *Interim Guidelines, Reliability Improvement Warranty (RIW)*, U.S. Air Force, Hq., Directorate of Procurement Policy (AF/LGP), DCS/Systems and Logistics (1974).

Provides guidance with respect to RIW application criteria; funding of RIWs; essential elements to be included in an RIW contract clause; determination of cost effectiveness of use of an RIW provision; and evaluation approaches that can be used to assess the cost effectiveness of an RIW after it has been implemented.

28. *Long Term Service Warranty Contracts--A Case Example of Gyroscopes Purchased Under Warranty*, Joseph L. Higgins, Air Force Institute of Technology (Ohio: Wright-Patterson Air Force Base, 1972).

Analyzes Air Force organizational and managemental aspects of long-term service warranty contract provisions using an Air Force contract for an aircraft gyroscope as a vehicle for analysis. Two areas of analysis were warranty funding and warranty data requirements.

29. *Magnuson-Moss-Warranty Federal Trade Commission Improvement Act,* Public Law 93-637; 88 STAT. 2183.

Act provides minimum disclosure standards for written consumer product warranties, defines minimum Federal content standards for such warranties, and amends the Federal Trade Commission Act in order to improve its consumer protection activities.

30. "Managing Downstream Weapons Acquisition Costs--Some Key Elements," Russell R. Shorey, *Defense Management Journal*, January 1976.

Discusses O&S cost visibility, O&S cost-related thresholds, design trades to minimize LCC, contract and other incentives to reduce O&S costs, and logistics alternatives.

31. *Methods of Acquiring and Maintaining Aircraft Engines* (Washington, D.C.: Logistics Management Institute, 1972).

Discusses a mathematical model constructed to compare military and commercial differences in practice that would affect the use of warranties. The report recommends against the use by DoD of aircraft engine warranties but encourages continued research and analysis into specific applications.

32. *(A) Model for Contract Pricing for Use by Government Depots in Conjunction with the Use of Government Depot Warranties in Multi-Year Contracting at Fixed Prices*, Don E. Hunt, AGMC 74-013II (Ohio: Aerospace Guidance and Metrology Center, Newark Air Force Station, 1974).

Examines the fundamental economic considerations of the maintenance warranty concept embodied in fixed-pricing and multi-year contracting. A model is developed that incorporates these concepts into a government depot maintenance warranty.

33. "(A) Monte Carlo Risk Analysis of Life Cycle Cost Prediction," Samuel B. Graves, Air Force Institute of Technology thesis (Ohio: Wright-Patterson Air Force Base, 1975).

Investigates the uncertainties involved in the prediction and measurement of life-cycle costs. The logistics supportability incentives in the F-16 contract are analyzed in light of the stochastic uncertainties of prediction and measurement of logistics support costs. A Monte Carlo simulation model is applied to determining appropriate contractor rewards or penalties.

34. "(A) New Approach to Long Range Fixed Price Warranty Within Operational Environments--Buyer/User," Oscar Markowitz, *Annals of Reliability and Maintainability (1971)* (New York: Institute of Electrical and Electronics Engineers, Inc., 1971), pp. 252-58.

Discusses the Lear Siegler/Navy gyro contract from the buyer-user viewpoint.

35. "(An) Overview of RIW Procurement," Harold Balaban, paper presented at Joint Logistics Commanders Conference, Airlie House, Warrenton, Va., May 1975.

Presents guidance for structuring the warranty. Discusses the warranty concept, RIW terms and conditions, and RIW development.

36. "(A) Practical Life Cycle Cost/Cost Ownership Type Procurement Via Long Term/Multi-Year 'Failure Free Warranty' (FFW) Showing Trial Procurement Results," James C. Harty, *Annals of Reliability and Maintainability (1971)* (New York: Institue of Electrical and Electronics Engineers, Inc., 1971), pp. 241-51.

Discusses the Lear Siegler/Navy gyro contract from the designer-supplier viewpoint.

37. *Proceedings of Failure Free Warranty Seminar* (Philadelphia: U.S. Navy Aviation Supply Office, 1973).

Reports on such FFW subject areas as: introduction to FFW, contractual considerations, case studies, overhaul shop practices, Navy 3M data, and analytical techniques.

38. *Project ACE--Findings and Action Plans,* Air Force Systems Command (Andrews Air Force Base, Camp Springs, Md., 1973).

Project ACE (Acquisition Cost Evaluation) studied opportunities for achieving drastic reductions in weapon system acquisition and ownership costs. Findings relating to reliability improvement and long-term warranties are included.

39. *Reliability Acquisition Cost Study,* Salvatore P. Mercurio and Clyde W. Skaggs, General Electric Company, RADC-TR-73-334 (Griffiss Air Force Base, New York: Rome Air Development Center, 1973).

Develops basic relationships capable of determining and predicting the acquisition costs attributable to equipment reliability. Relationships were developed using data from two manufacturers on ten equipments covering three reliability elements.

40. "Reliability Augmentation Maintenance Program, Altimeter Receivers-Transmitters (RAMPART)-Warranty Program," James J. Larkin, *Proceedings of Quarterly Meeting of the Life Cycle Cost Task Group of the Joint Services Data Exchange for Inertial Systems,* San Diego, Calif., February 24-26, 1976.

Uses vugraphs to discuss the depot overhaul of the APN-141 altimeter receiver-transmitter. Vugraphs cover the RIW concept, benefits, advantages, disadvantages, cost-effective design changes, rework procedures, changes in maintenance concepts, and LCC savings.

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THE IMPACT OF RELIABILITY GUARANTEES AND WARRANTIES ON ELECTRON--ETC(U)
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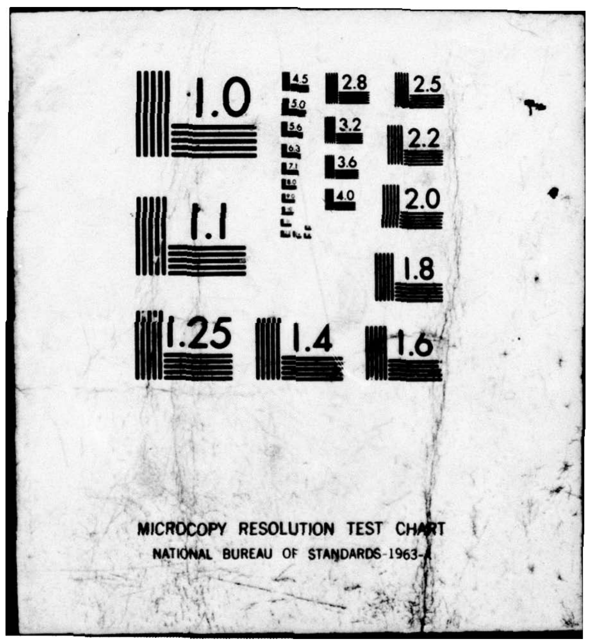
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41. "Reliability Improvement Warranty: An Experimental Logistics Support Concept," Ronald A. Mlinarchik, *Proceedings of the 14th Annual US Army Operations Research Symposium,* Fort Lee, Va., November 1975.

Discusses what RIW is, how concept was developed, policy that governs it, potential benefits, how it works, and some examples of its use by the Services. Highlights of the CONUS NAV Program RIW clause are discussed. An overview of RIW evaluation techniques is presented with emphasis on cost effectiveness, reliability growth, risk, and suitability. RIW problems and solutions are presented.

42. *Reliability of Military Electronic Equipment,* Advisory Group on Reliability of Electronic Equipment (AGREE), Office of the Assistant Secretary of Defense (Research and Engineering) (1957).

The landmark report on reliability of electronic equipment.

43. "Reliability Planning and Management (RPM)," J. D. Selby and S. G. Miller, presented at American Society for Quality Control Seminar, Niagara Falls, N.Y., September 1970.

Explains use of RPM, a management tool for bridging the gap between stated reliability requirements and implementation planning.

44. "Reliability Tasks vs. Product Reliability," David I. Troxel, *Proceedings 1969 Annual Symposium on Reliability,* Chicago, Ill., January 21-23, 1969 (New York: Institute of Electrical and Electronics Engineers, Inc., 1969).

Analyzes various reliability tasks with regard to their interrelationship and applicability to meeting requirements.

45. "Reliability: What Happens If...?," Ervin F. Taylor, *Proceedings 1969 Annual Symposium on Reliability,* Chicago, Ill., January 21-23, 1969 (New York: Institute of Electrical and Electronics Engineers, Inc., 1969).

Examines both the quantitative and qualitative approaches to a reliability program. Quantitative disciplines include prediction, risk analysis, and measurement. Qualitative disciplines include design review, FMECA, parts-material

review, specifications and standards, failure evaluation, configuration control, maintenance programs, and integrated test programs.

46. "Source Selection and Contracting Approach to LCC Management," J. W. Stansberry, *Defense Management Journal,* January 1976.

Discusses RIWs briefly along with LCC and source selection.

47. "Study of Warranted Items," Robert E. Black, Jr., Management & Intern Project, Defense Supply Agency, Defense Contract Administration Services, September 1972.

Reports on a general study of warranties in government contracts. Covers procurement regulations and warranty knowledge, identification processing, and administration.

48. *Techniques for Selecting and Analyzing Reliability Improvement Warranties,* Joseph A. Bizup and Randall R. Moore, R-7505 (Washington, D.C.: Naval Weapons Engineering & Support Activity, 1975).

Presents selection criteria for RIW candidates. Techniques for risk and economic analysis are developed. Three contracts are analyzed in detail with respect to RIW impact on item procurement and management. The cost-effectiveness of two contracts is discussed to indicate areas of probable life-cycle-cost savings.

49. *(The) Use of Warranties for Defense Avionics Procurement,* H. Balaban and B. Retterer, ARINC Research Corporation, RADC-TR-248 (Griffiss Air Force Base, New York: Rome Air Development Center, 1973).

Investigates potential benefit of using warranty agreements as part of military avionics procurements. Interviews were conducted with warranty users, and a life-cycle cost model was formulated. The major conclusion is that a properly constituted and applied warranty can yield significant reliability and life-cycle-cost benefits and that broader use of warranties is advisable.

50. "Warranties as a Life Cycle Cost Management Tool," C. R. Knight, *Defense Management Journal,* January 1976.

Discusses LCC management, basic limitations in achieving reliability of the government customer, the burden on the manufacturer, the responsibility for total cost, the limitations of warranties, and the associated risk of warranties.

51. "Warranties as a Life-Cycle-Cost Management Tool," C. R. Knight, *EASCON '74 Record* (New York: Institute of Electrical and Electronics Engineers, Inc., 1974).

Discusses use of warranties to control life-cycle costs of military equipments as an alternative to standard procurement approaches.

52. "Warranties: DoD Initiates Trial of Reliability Improvement Warranties in Buying Electronic Equipment," *Federal Contracts Report,* November 10, 1974 (Washington, D.C.: The Bureau of National Affairs).

Discusses OSD memorandum that provides guidelines for new RIW to be applied in electronics field.

53. *Warranties for Military Avionics Procurement,* R. E. Adel, (Hawthorne, Calif.: Northrop Electronics, 1975).

Presents history of warranties and discussion of commercial airline experience. Discusses limited applications to military programs and provisioning details of RIWs.

54. "Warranties Under Government Contracts," J. G. Twomey, *Insurance Law Journal,* August 1970, pp. 464-71.

Discusses the need for articulation of a warranty policy on government contracts that would provide the government the protection it needs and can afford, and that would provide uniform fair treatment for its contractors, subcontractors, and suppliers.

55. "Warranty Cost Estimates for Avionic Subsystems," P. O. Nerber, *Proceedings 1969 Annual Symposium on Reliability,* Chicago, Ill., January 21-23, 1969 (New York: Institute of Electrical and Electronics Engineers, Inc., 1969).

Presents a general and analytical technique for estimating the failure and cost exposures associated with a warranty commitment on avionic systems.

56. "Warranty Guarantee and Contractor Exposure to Cost Penalties," Robert McGinns, *Proceedings of Quarterly Meeting of the Life Cycle Cost Task Group of the Joint Services Data Exchange for Inertial Systems,* San Diego, Calif., February 24-26, 1976.

Discusses the types of cost penalties, adjustments, and other considerations that were identified after review and analysis of a specific RIW contract. Includes for each specific type of consideration, the amount of contractor risk or exposure to cost penalties, a parametric analysis, and identification of critical areas for management attention.

57. "Warranty Procurement--A Case History," Harold S. Balaban and Frederick J. Nohmer, *Proceedings of the 1975 Annual Reliability and Maintainability Symposium,* Washington, D.C., January 1975 (New York: Institute of Electrical and Electronics Engineers, Inc., 1975).

Gives a case history of the development of a complete warranty provision for the Air Force ARN-118 TACAN.

58. *World Airline Suppliers Guide* (Washington, D.C.: Air Transport Association of America).

Covers commercial airline warranties (chapter 10).